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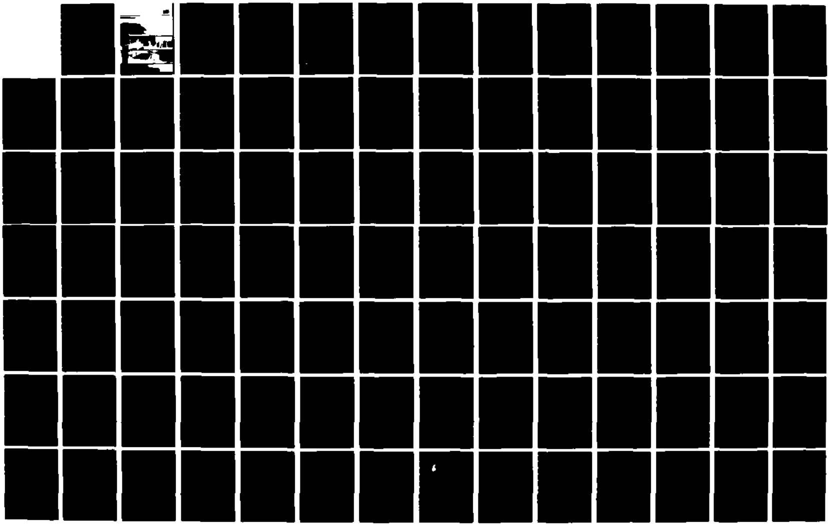

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MICROCOPY RESOLUTION TEST CHART
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Chesapeake Bay Low Freshwater Inflow Study

APPENDIX B - PLAN FORMULATION
APPENDIX C - HYDROLOGY
APPENDIX D - HYDRAULIC MODEL TEST

10

September 1984

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Chesapeake Bay is a complex estuarine system that is dependent on the freshwater inflow from its tributaries to maintain the salinity regime that characterizes its ecosystem.

Increasing population and economic growth in the Bay drainage area is predicted to result in increased water supply demands and attendant increases in the amount of water used consumptively. This will cause a marked reduction in freshwater inflow to the Bay and result in higher salinities throughout the Bay

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20. ABSTRACT

system. In the long term, salinities would be expected to increase by as much as 2 to 4 ppt.

The Low Freshwater Inflow Study methodology involved selecting representative species for study, mapping potential habitat under various conditions, using expert scientists to interpret the significance of habitat change, and assessing socio-economic and environmental impacts of the changes.

While no specific plan was developed to solve the problems caused by reduced freshwater inflows, several alternatives were identified as "most promising". These include reservoir storage, conservation, growth restriction, oyster bed restoration, and fisheries management.

The final report recommends that a comprehensive water supply and drought management study be conducted that will identify those measures required to optimize the use of existing water supplies in the Bay drainage basin and minimize reductions in freshwater inflow to the Bay.

Chesapeake Bay Low Freshwater Inflow Study

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APPENDIX B - PLAN FORMULATION
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US Army Corps of Engineers
Baltimore District

September 1984

CHESAPEAKE BAY

LOW FRESHWATER INFLOW STUDY

APPENDIX B

PLAN FORMULATION

Department of the Army
Baltimore District, Corps of Engineers
Baltimore, Maryland
September 1984

CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
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PLAN FORMULATION

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CHAPTER I

INTRODUCTION

The overall goal of the Low Freshwater Inflow Study is to identify the most promising solutions to the problems caused by reduction in freshwater inflows to Chesapeake Bay. Presented in this appendix are investigations of possibilities for management, development, or preservation that may alleviate identified problems related to low freshwater inflow and take advantage of potential opportunities in Chesapeake Bay. An iterative process was used to increasingly refine the magnitude and scope of alternative plans toward a range of feasible actions that would, as far as possible, maximize contributions to Bay resources and other values.

FEDERAL OBJECTIVE

Guidelines for the formulation and evaluation of plans for improvement for all Federal water and related land resource activities are contained in the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, March 1983. As stated therein, the single Federal objective of water and related land resource planning is to contribute to National economic development consistent with protecting the Nation's environment, pursuant to National environmental statutes, applicable executive orders, and other Federal planning requirements.

PLANNING OBJECTIVES

The significant economic, social and environmental problems and opportunities resulting from reduced freshwater inflow have been presented in Appendix A, Problem Identification. Based on this, and within the framework of the Federal objective, planning objectives for the Low Freshwater Inflow Study have been developed. The objectives provide a focus for development of plans to protect highly valued habitats or otherwise mitigate the short and long-term effects of drought and consumptive losses. They are specific to individual aquatic resources in Chesapeake Bay. The planning objectives are:

1. Protect productive oyster beds from incursions of disease organisms and predators, or otherwise alleviate these damages, for purposes of long-term commercial fishery productivity and Bay traditions.

2. Maintain the size of tidal freshwater and oligohaline salinity zones for their value in ecosystem functions and as a spawning and nursery area for numerous commercially and recreationally important species such as striped bass, shad, spot, menhaden, and alewife.

3. Maintain and/or enhance the productivity of striped bass and shad which are important in commercial harvests, recreation and Bay traditions.

4. Contribute to the propagation of submerged aquatic vegetation for benefit of waterfowl (important components of recreational hunting and Bay traditions) and ecosystem processes.

5. Contribute to the productivity of the clam, Macoma balthica, as an essential food for canvasback duck (an important component of recreational hunting and Bay traditions).

6. Contribute to the productivity of the soft clam, Mya arenaria, for its commercial harvest values.

7. Reduce the potential for incursion of wood borers, Bankia and Teredo, to avoid economic losses at boating harbors.

8. Moderate the proliferation of sea nettles to contribute to water contact recreation experience and aesthetic environmental values.

CONSTRAINTS AND ASSUMPTIONS

Limitations on the full array of options available for successful response to the planning objectives (i.e., "constraints") are imposed on the planning setting by technical, environmental and institutional factors and public perceptions. Based on recommendations of the Biota Evaluation Panel, certain guidelines and procedures were adopted for use in the planning process. These are:

1. Pursue a highly conservative policy toward alterations in the quantity of freshwater inflow, recognizing the high biological value of Chesapeake Bay and acknowledging the limits of predictive capability.

2. Retain the fundamental seasonal freshwater inflow pattern of low flows in the fall and high flows in the spring.

3. Recognize that upstream shifts of species will frequently move them into lower valued habitat.

Major assumptions made in plan formulation include:

1. The use of salinity tolerance alone, in conjunction with knowledge of the habitat variables substrate and depth, is sufficient to permit meaningful alternative plan development and evaluation.

2. The selected "study species" provide a sufficiently adequate representation of all Bay biota to permit the formulation of generalized problem solutions.

3. By the year 2020, the goals of the 1976 Amendments to the Water Pollution Control Act would be met. Therefore, water quality parameters other than salinity would not be a plan evaluation variable.

CHAPTER II

POTENTIAL MEASURES

A variety of measures could be employed to offset the effects of reduced freshwater inflows. The potential measures can be characterized as being either "flow supplementation, or "Chesapeake Bay management." Flow supplementation measures are alternatives which can be employed in the Bay's tributary drainage basins to provide increased freshwater inflow. Included in this category are conservation measures, growth restrictions, water pricing and metering, drought emergency measures, reservoir storage, importation of water from other basins and development of groundwater. The Chesapeake Bay management measures address directly the Bay's resource related impacts. Included in this category are fisheries management (catch restriction and finfish restocking), oyster bed restoration and salinity barriers.

SCREENING OF MEASURES

Measures of all types were evaluated as to their applicability and acceptability for use in alleviating low-flow related problems. At the present time, the state of the art knowledge of detailed applications of the Chesapeake Bay management type alternatives is limited. Therefore, only one level of screening was done for them. This screening was oriented to eliminating those measures which obviously were not technically or institutionally feasible at the present time. Further refinement of these Chesapeake Bay alternatives was limited to an assessment of their applicability to various portions of the Bay and the estuarine portion of its tributaries.

Flow Supplementation Measures

As stated above, the flow supplementation measures considered were conservation, drought emergency measures, reservoir storage, growth restrictions, importation of water, and groundwater development.

Conservation. Conservation consists of measures that reduce water demands or withdrawals. A reduction in demand could also result in a reduction in consumptive losses. This would have the net effect of increasing river flow over the projected future condition. The potential reduction in consumptive losses is presented in a later section of this chapter.

Reservoir Storage. Reservoirs are structures that are used to store water during periods of surplus for release during periods of low flow or drought. These measures allow direct management of flows during specific periods for the benefit of specific Bay resources. In general, storage can be accomplished through construction of new projects or reallocation of storage from existing projects. An in-depth analysis of the potentials for storage in the Bay's major drainage basins is included in a later section.

Drought Emergency Measures. Drought emergency measures are any of a variety of public laws which could require specified users to curtail water use. Often included are bans on such activities as lawn sprinkling and car washing. The consumptive losses thus eliminated would contribute directly to streamflow. Even though the savings in consumptive losses associated with drought emergency measures are small, it was

retained for further investigation. Quantification of the savings in consumptive losses that could be expected are presented in conjunction with the conservation write-up in a later section of this chapter.

Restricted Growth. Even more far reaching and permanent in its effect than drought emergency measures is the option of regulating entirely against population growth or specific water uses, in a particular area. Regional development policies could be implemented to control growth patterns and associated water uses. Or, regulations could conceivably be placed against a specific type of water use itself, such as irrigation. These, in effect, would prevent consumptive losses and thereby assure maintenance of freshwater inflow to the Bay.

The amounts of water that could be saved would be a function of the quantities and types of water use in each basin and the levels of regulation imposed. Due to the many combinations that could occur, specific plans for restricted growth were not formulated. However, these regulations on water use were carried forward as promising alternatives.

Pricing and Metering. The price of water supplied through central water supply systems usually is about the same as the cost of providing the service. Billing is normally accomplished either through a flat-rate system, in which all customers pay equally, regardless of the volume of water used, or through metering. Metering of supplies to customers is a means of linking the price of water to the quantity of water consumed. Reductions in residential water demands of 40 percent have been recorded following installation of meters. It is not clear, however, whether the reduction is due to the increase in the price of water or to the awareness of being charged for each unit consumed. Since an inventory of metered services in the individual Bay basins was not available, the potential water savings due to increased metering has not been pursued further.

Adjustment of water consumption habits through pricing itself is an additional potential measure. It would be expected that an increase in the price of water would lead to a decrease in the amount of water consumed. Except for agricultural and industrial users, however, which are very sensitive to price changes, there are no reported field data that indicate how rate structuring actually affects water consumption. The few studies available indicate, however, that water is somewhat price inelastic for domestic water users. This is due to a combination of factors including the basic necessity for water, indoor vs. outdoor use, and affluence.

Pricing could be useful in reducing demand in centralized water systems that provide a large quantity of water to industry. But, decreases in consumptive losses could be small or could even increase. This is due primarily to projections of technological developments and recycling in pursuit of water quality. Industrial water use technologies are projected to reduce water demands, but would have no effect in reducing future consumptive losses.

Because of the apparent small decreases in consumptive losses that would result from water pricing, it was dropped from further consideration.

Importation of Water. The importation of water into the Chesapeake Bay Basin from an adjacent drainage basin could significantly increase freshwater inflows. This alternative

was considered briefly, but was dropped in light of the apparent high costs and potential adverse impacts in the other basins. It should be noted that there are some existing and potential interbasin diversions within the Bay drainage. However, the impact of these diversions on the freshwater entering the Bay is felt to be minor.

Groundwater Development. Major upstream groundwater development could be used to provide supplemental water during low flow periods. This measure was also dropped in consideration of the high costs and the likely adverse impacts of large withdrawals on local groundwater users.

Chesapeake Bay Management Measures

The second of the two major types of measures are the Chesapeake Bay management measures. These are actions which may be employed within the more immediate tidal Chesapeake to solve low-flow related problems. These include resource management options such as oyster bed restoration, fisheries management, SAV reestablishment and salinity barriers.

Salinity Barriers. Salinity barriers, in the form of solid structures constructed across a portion of the Bay or one of its subestuaries, could prohibit the intrusion of high salinity waters. While effective in reducing salt water intrusion, potential negative effects include: 1) reducing the normal flushing action of a subestuary, 2) interrupting the normal movements of aquatic organisms, and 3) disrupting commercial shipping. Further, a detailed analysis of barrier plans would probably require model testing. Thus, due to the degree of adverse impact and inability for additional model testing, salinity barriers were dropped from further consideration.

Fisheries Management. Given the importance of commercial and sport fishing to the Chesapeake Bay Region, it is not surprising that the involved states all have comprehensive fisheries programs and attendant research and resource study programs. Some programs are currently focused on species such as shad and striped bass which are severely depleted in Chesapeake Bay. The alternative to be considered is modifying the existing programs of the states in order to be more responsive to the problems and needs identified in the Low Freshwater Inflow Study. Given the problem species and areas, the state resource agencies will be better able to target catch restrictions, minimum length requirements, hatchery programs and other measures to aid those commercially and recreationally important species that are adversely impacted by low freshwater inflows. A quantification of the benefits of the fisheries management measures was not attempted since, at the present state-of-the-art, the relationships of these measures to fishery populations in the estuary are uncertain. However, the restocking of finfish such as striped bass and shad, as well as catch restrictions for these species and oysters, have potential for correcting drought and long-term average problems. They will thus be discussed further in the discussion of "most promising" alternatives (Chapter V).

A peripheral issue exists relative to the reproductive success of freshwater spawners in Chesapeake Bay. Among these are shad. Shad historically migrate from the ocean to spawn in freshwater rivers and streams. The obstruction of most major rivers in the Bay area by dams has reduced the potential freshwater habitat accessible by the fish for spawning. The effect of this on populations of shad can only be surmised, but it is likely that significant negative effects are due to the dams. Fish ladders, to allow passage of

fish around the dams, are frequently recommended by Bay fisheries experts. Thus, while only measures for dealing with the effects of reduced freshwater inflow will be dealt with in this analysis, an additional existing issue is the problems of barriers to fish migration. Evaluation of this option is not possible within the scope of this study.

SAV Reestablishment. Currently, submerged aquatic vegetation are substantially reduced in Chesapeake Bay. Programs have been initated sporatically in attempts to reestablish beds that have been lost, but success has been irregular. Reasons for the SAV decline are largely unknown, although the EPA Chesapeake Bay Program has identified likely candidates that include a reduction in available sunlight due to nutrient enrichment and sediments.

Even with this knowledge, it is highly questionable whether a SAV reestablishment program would be successful. Many unknowns remain, both in the factors that control the life cycles and in appropriate planting procedures. Therefore, further research is required before SAV reestablishment can be considered a viable alternative.

Oyster Bed Restoration. This measure incorporates the various processes involved in improving the productivity of oysters. Included are creation and restoration of oyster beds through placement of clean oyster shell. Typically, this material is either mined from ancient bottom deposits or is obtained from oyster shucking houses. It is placed in locations on the Bay bottom where good spat set is expected. Spat set in Chesapeake Bay normally occurs during the period from June to mid July. Generally, a condition of increasing salinities during this period has been observed to be beneficial for a good set.

The oysters that grow in the restored beds can either be transferred to enchance oyster productivity over wider areas or left in place. The process of relocating 1-year old oysters to new locations is known as seeding. The seeded beds are allowed to mature for 2 to 3 years before they are harvested.

As part of an overall repletion program conducted by the State of Maryland, oyster seeding has largely been credited with alleviating the effects of MSX and small spat sets. Successful programs have also been initiated in Virginia. These successes highlight the potential of oyster bed restoration in offsetting losses in oyster productivity due to increased disease mortality resulting from low freshwater inflows. The general effectiveness and feasibility of this measure made it a candidate for retention as a most promising alternative.

RESULTS OF PRELIMINARY SCREENING

The above screening of potential measures was conducted to identify those measures warranting further consideration. Based on this screening, the following measures are felt to be generally feasible and beneficial:

FLOW SUPPLEMENTATION

Reservoir Storage
Conservation
Drought Emergency
Growth Restrictions

CHESAPEAKE BAY MANAGEMENT

Oyster Bed Restoration
Catch Restrictions
Finfish Restocking

At the present time, the state-of-the-art knowledge of detailed application of the Chesapeake Bay management measures is limited. Therefore, screening was oriented to identifying those measures that appeared to be technically and institutionally feasible at the present time. Further refinement of the Chesapeake Bay management measures was limited to an assessment of their applicability to various portions of Chesapeake Bay and the estuarine portions of its tributaries (see Chapter V).

Similarly, among the flow supplementation measures, precedence for and data concerning growth restrictions are limited at the present time. Thus, further discussion of the applicability of this measure is also limited to Chapter V. The remaining flow supplementation plans, including reservoir storage, conservation and drought emergency, are sufficiently well known to warrant further attention. An investigation of their potential for supplementing flows is provided in the following section.

REFINEMENT OF FLOW SUPPLEMENTATION MEASURES

To provide a basis for formulation of specific plans, an inventory and further investigation was conducted for the storage, conservation and drought emergency types of flow supplementation measures.

Upstream Storage

Upstream storage measures include the potential for both reallocation of existing storage and the development of new storage. Storage availability was considered for the Susquehanna, Potomac, James, Rappahannock and York Rivers. Together these comprise approximately 90 percent of the Bay's average inflow. Other major rivers are either completely developed (e.g., Patuxent) or lacking in significant storage capability (e.g., Choptank and Nanticoke). Unit costs for storage were also developed based on recent construction experience for several major projects within the region.

Storage Volumes. The initial step in the storage analysis was to develop an inventory of existing Federal and non-Federal projects within each of the major drainage basins having a total storage over 10,000 acre-feet. Given this inventory, it was assumed that up to 50 percent of the conservation storage that was not already committed for low flow augmentation storage could be reallocated for release to the Bay. It was further assumed that any flood control storage above three inches could also be reallocated for low flow augmentation.

While reallocations of this magnitude would have beneficial low flow augmentation impacts, there would likely be major adverse recreation and fish and wildlife impacts within the reservoir areas of most of the projects. Further, the loss of flood control storage would probably be perceived as a major adverse impact even if the loss of benefits is minor. After considerations of the various reallocation assumptions, it was decided that a practicable reallocation level would be 20 percent of the present

conservation storage. Further, no flood control storage would be reallocated for low flow augmentation.

Consideration was also given to the construction of new storage projects. The potential projects initially identified included those Federal and non-Federal projects that were under construction, authorized, recommended for construction, or found to have merit in recent comprehensive basin studies. This inventory was then screened, and new reservoir projects which appeared to have the most merit were selected for each of the major basins. A comprehensive inventory of potentially reallocable storage sites and potential new reservoir storage sites, along with the associated costs of each, are presented in Attachment A for the Susquehanna, Potomac, James, and Rappahannock Rivers.

While the combination of reallocable and potential new storage volumes is assumed to represent a reasonable and implementable upper limit of storage, one other factor was added in the development of the reservoir storage criteria for use in plan formulation. One of the adopted constraints for plan formulation is the retention of the natural seasonal variation in freshwater inflow to Chesapeake Bay. In order to assure achievement of this goal, feasible storage in each basin was limited to 5 percent of the average annual discharge of the river. Thus, the reasonable upper limit of reservoir storage considered in plan formulation was a function of either the physical capacity of reallocable plus new storage or the 5 percent criteria. Table B-II-1 presents these values for each river being considered.

TABLE B-II-1

POTENTIAL UPSTREAM STORAGE
CHESAPEAKE BAY DRAINAGE AREA

Basin	Reallocable Storage		New Storage		Physically Available Storage (ac-ft)	Maximum 5 Percent Storage (ac-ft)
	Non-Fed (ac-ft)	Federal (ac-ft)	Non-Fed (ac-ft)	Federal (ac-ft)		
Susquehanna	85,100	130,400	184,100	800,500	1,200,100	1,418,000
Potomac	-	-	11,100	384,700	395,800	449,000
James	-	-	-	1,115,000	1,115,000	370,000
Rappahannock	-	-	-	713,000	713,000	106,000
York	-	-	-	-	-	96,000
TOTALS	85,100	130,400	195,200	3,013,200	3,423,900	

Conservation and Drought Emergency

Water conservation and drought emergency measures are nonstructural means of providing additional instream flow. Through demand management techniques, use of water is reduced, less water is withdrawn, and, generally, consumptive losses are lowered. This results in more water remaining to flow to the Bay. The investigation of potential water use savings through conservation and drought emergency in Chesapeake Bay begins with the original projections of water use and consumptive loss presented in Appendix C, Hydrology.

Use categories considered in the original projections were public-domestic-commercial, manufacturing, power, irrigation, livestock, and minerals. These are the water uses that are targeted for reduction through conservation and drought emergency measures.

The total reduction in consumptive losses that can be achieved through the various levels of conservation and drought emergency measures are shown in Table B-II-2. Derivation of these values are presented in Attachment B.

TABLE B-II-2

AVERAGE ANNUAL 2020 CONSUMPTIVE
LOSS REDUCTIONS BY CONSERVATION LEVEL
(MGD)

Inflow Point	Year 2020 Consumptive Losses	Conservation			Conservation and Drought Emergency		
		Low	Medium	High	Low	Medium	High
15	992	89	178	281	149	232	320
1	105	1	2	6	8	9	10
2	4	-	-	-	-	-	-
3	25	-	-	-	-	-	-
4	226	2	4	8	19	19	21
5	98	8	14	22	13	19	26
6	54	4	5	6	9	9	9
11	14	1	2	3	2	3	3
13&14	389	13	27	45	40	52	69
16	14	-	-	-	-	-	-
17	30	3	6	10	6	9	12
19	72	9	17	25	15	22	30
20	34	1	2	3	4	4	5
21	18	-	-	-	-	-	-
7	6	-	-	-	-	-	-
8	10	-	-	-	-	-	-
9	2	-	-	-	-	-	-
10	470	25	50	85	64	85	111
TOTAL		156	307	494	329	463	616

Values are presented for each inflow point used in the Low Freshwater Inflow hydraulic model test. Data were developed for only those basins in which at least a 1 mgd decrease in consumptive loss could be attained. The numbers shown for conservation and drought emergency are equivalent to the assumed increase in streamflow.

Implementation of conservation and drought emergency plans would be very difficult and costly in an area as large and diverse as the Cheasapeake Bay Basin. A basin-wide conservation plan would require extensive coordination to make it consistent and effective. Existing communities would require large amounts of retrofitting of new water-saving plumbing fixtures. Other water uses, such as irrigation and power, would require perhaps even more costly changes in hardware and/or water use technology.

In view of these factors, it was decided that, for purposes of effectiveness and efficiency in application, only river basins with the potential for average annual reductions in consumptive losses of 10 percent or greater would be retained for further consideration. These basins include the Susquehanna, Potomac, James, Rappahannock, Patuxent, Chester, and Choptank.

CHAPTER III

PHASE I FLOW SUPPLEMENTATION ALTERNATIVES

The capability of reservoir storage, conservation and drought emergency measures to supplement freshwater inflows was addressed in the previous chapter. The potential of reservoir storage for solving the identified problems will be explored in this chapter. All other promising plans, including growth restrictions and the Bay management measures, were not addressed in detail. While growth restrictions were felt to be feasible for regional planning, formulation of specific plans was not possible within the scope of this report. Similarly, due to the limited knowledge of management measures, only a preliminary investigation was conducted for them. Growth restrictions and the identified promising Bay management measures, however, have been retained for further consideration as most promising alternatives in Chapter V.

Reservoir storage plans were developed in response to both the Federal objective and the specific planning objectives presented earlier. In Phase I of plan formulation, only the Main Bay and Susquehanna River Basin were considered. This was done in order to evaluate the potential of reservoir storage in protecting valued habitat under a variety of freshwater inflow conditions. A range of plans, for both drought and consumptive loss related problems were developed and evaluated in an effort to maximize benefits through habitat protection or enhancement. Storage availability in the Susquehanna River Basin was the principal variable for screening of Phase I plans.

PLANNING CRITERIA

To provide a basis for plan development, an analysis was conducted to determine the appropriate seasons and salinities required to offset the specific problem associated with each planning objective. Most of this effort was based on the Report of the Biota Evaluation Panel, the two biota assessment contract reports by Western Eco-Systems Technology (WESTECH) and contacts with other experts on the biota of Chesapeake Bay. See also Appendix A (Problem Identification) for further discussion of the environmental variables affecting the biota. Planning criteria are summarized in Table B-III-1.

DROUGHT PLANS

For each species, a series of plans were developed to offset the adverse effects of drought. These were based on the adopted criteria for the critical season and salinity for each species and knowledge of the most valued habitats. Plan descriptions are presented in Table B-III-2. For oysters, for example, there are four plans, each representing the location of the 15 ppt line during a given freshwater inflow condition. The location of these salinity goals are shown on Plates B-I through B-XIV, located at the back of this volume.

For each organism of principal concern, the "No Action" plan is the Future Drought freshwater inflow condition. This condition represents the worst case scenario that could be expected within the planning horizon without a plan. The opposite extreme is the salinity corresponding to Base Average Freshwater inflows or an arbitrary goal oriented to the protection of particularly highly valued habitats, or protection of Bay resources,

TABLE B-III-1
PLANNING CRITERIA

Species or Association	Planning Objective	Critical Season	Salinity of Concern	Valued Areas
Oyster	MSX, dermo & drills control	SP	15	All oyster beds in Maryland north of Upper Tangier Sound, and tributaries in Virginia and seed beds in both MD & VA as shown in Plate B-I.
Oligohaline Zone	Maximize Size of Zone	SP,SU,F,W (in order of priority)	0.5-5.0	All habitat areas within salinities 0.0 to 5.0 ppt, as shown in Plates B-IV to VIII.
Tidal freshwater zone	Maximize Size of Zone	SP,SU,F,W	0.0-0.5	
SAV	Maximize Seed germination propagation	Sp, Su	0-12	All areas between 0 and 12 ppt depicted in Plate B-IX; especially for waterfowl in in Potomac River and Main Bay North of Potomac River, and Rappahannock River.
Soft Clam	Maximize Adult (Commercial densities)	Su	8-14	Primary commercial areas are in the Main Bay and Chester River (see Plate B-XI for secondary areas).
Macoma Balthica	Maximize Adult survival (high density)	F	5-18	Value to Canvasback duck is prodominantly in the Main Bay and the Potomac River.
Bankia & Teredo	Reduce spawning success	Su	11	Principal boating areas in Severn, Magothy and South Rivers, and St. Michaels -Kent Narrows vicinities.
Sea Nettles	Reduce success of polyp development	Sp	5	Tributaries are predominant sea nettle development areas.

TABLE B-III-2

PHASE I PLAN FORMULATION
DROUGHT PLANS

[illegible]	Alternative Salinity Goals*	Season	Total Habitat Km^2	Habitat Change (from FD) Km^2	Habitat Change (from FD) %	Storage Required (1000's acre-ft) Low	Storage Required (1000's acre-ft) High
Oyster Disease-Reduction	15 ppt below Eastern Bay (FD = without Condition)	SP	1,150	-	-	0	0
"	15 ppt opposite Taylors Island (Base Drought)	SP	1,580	430	40	850	1,140
"	15 ppt in upper Tangier Sound (Future Average)	SP	2,250	1,120	99	7,370	9,610
"	15 ppt below South Marsh Island (Base Average)	SP	2,715	1,585	140	8,220	10,750
Tidal Freshwater Oligohaline Zone	5 ppt at Swan Pt. -- above Chester River (FD = W/O Condition)	SP	335	-	-	0	0
"	5 ppt at Love Pt. -- South of Chester River (Base Drought)	SP	990	105	-	850	1,140
"	5 ppt below North of Bay Bridge at Eastern Shore (Future Average)	SP	1310	220	-	7,370	9,610
"	5 ppt [illegible] Pt. on [illegible]	SP	1310	0	0	8,220	10,750

* For locations see Figures at back of this volume of the report.

TABLE B-III-2 (cont'd)

PHASE I PLAN FORMULATION
DROUGHT PLANS

Species/ Resource	Alternative Salinity Goals	Season	Total Habitat Km^2	Habitat Change (from FD) Km^2	Habitat Change (from FD) %	Storage Required (1000's acre-ft) Low	Storage Required (1000's acre-ft) High
Submerged Aquatic Vegetation	12 ppt from below mouth of Severn River to below Eastern Neck Island (FD = W/O Condition)	SP	650	-	-	0	0
"	12 ppt below West River on Western Shore (Base Drought)	SP	700	50	8	350	1,140
"	12 ppt below mouth of Choptank River (Future Average)	SP	1,020	370	57	7,370	9,610
Soft Clam	12 ppt opposite Gibson Island (FD = W/O Condition)	SU	0	-	-	0	0
"	14 ppt in vicinity of Bay Bridge (Base Drought)	SU	72	72	100	920	1,200
Bankia & Teredo Control	11 ppt above Magothy River (FD = W/O Condition)	SU	20,600 (slips affected)	-	-	0	0
"	11 ppt below Magothy River (Base Drought)	SU	15,500 (slips affected)	5,100	25	920	1,200

TABLE B-III-2 (cont'd)

PHASE I PLAN FORMULATION
DROUGHT PLANS

Species/ Resource	Alternative Salinity Goals	[illegible]on	Total Habitat Km^2	Habitat Change (from FD) Km^2	Habitat Change (from FD) %	Storage Required (1000's acre-ft) Low	Storage Required (1000's acre-ft) High
Macoma	18 ppt below mouth of Chester River (FD = W/O Condition)	F	760	-	-	0	0
"	18 ppt at Tilghman Point (Base Drought)	F	1,100	340	45	920	1,210
"	18 ppt below mouth of Choptank River (Future Average)	F	1,480	720	95	8,410	10,800

such as marinas and swimming waters. Identification of these highly significant habitats and/or Bay resources was based largely on the three reports referenced above, additional contacts with experts in the scientific community and in-house determinations. Valued habitats are described in Table B-III-1. Plans intermediate to the extremes of the "No Action" and "full protection" were developed to allow evaluation of the changes in habitat that occur with incremental modifications in freshwater inflow. Habitat changes for all of the drought plans are shown in Table B-III-2. The data indicate the amount habitat increases from Future Drought.

Estimates of the volumes of storage required in the Susquehanna River to maintain the identified habitats are also shown in Table B-III-2. These were derived based on the methods described in Attachment C. For preliminary plan development, the "low" estimate of 180 days (2 seasons) of flow supplementation is assumed. The storage volumes shown also include allowances for releases from storage in two consecutive years to offset an assumed three-year event. It was assumed that reservoirs will not refill significantly during the intervening months between the releases.

LONG-TERM AVERAGE PLANS

Long-term average plans are premised on the concept that Bay resources should be protected against long term diminution due to gradual reductions of freshwater inflow in the future. These plans are generally specified for the same seasons as the drought plans with the exception of the oyster disease control and tidal freshwater/oligohaline zone plans. These later two plans are in recognition of the possible need for protection of oyster beds and the oligohaline zone year around. The long-term average plan for each organism is described in Table B-III-3. The salinity goals associated with each preliminary plan are depicted as isohalines on Plates B-I through B-XIV. Of these, the isohaline locations for the year-around average plans for oyster and tidal freshwater/oligohaline zone plans are shown in Plates B-III and B-VIII.

The long-term average "no action" plans, as listed in Table B-III-3, are equivalent to Future Average freshwater inflow conditions. These differ from the Base Average condition by the amount of the incremental consumptive losses that have been projected to occur by the year 2020. The "full protection" plan, as shown in Table B-III-3 for each organism, represents the level of freshwater inflow that is felt to protect the essential character of each Bay species or species association. In each case, except for submerged aquatic vegetation (SAV) and sea nettle, this is taken as Base Average freshwater inflow conditions. For SAV and sea nettle, the upper-level plan proposed is an enhancement plan. SAV are an essential element in the Bay ecosystem and may benefit from flows in excess of the Base Average. Sea nettle densities will theoretically be reduced in the summer recreational season through augmentation of spring flows to reduce polyp development. Habitat changes for the array of long-term average plans for each organism are also shown in Table B-III-3. For oyster and the oligohaline/tidal freshwater zone, habitats are computed based on the year-around average location of the appropriate isohalines. Habitat for all other organisms and the storage required during the specified seasons are also shown in Table B-III-3. The storage volumes are computed assuming flow supplementation would be required two consecutive years.

[illegible]

[illegible] LOWER [illegible] STORAGE PLAN [illegible]

[illegible]	[illegible] Level	Est. [illegible] Km^2	Habitat Change Grow (D) Km^2	Habitat Change Grow (D) %	Action Season	Storage Required (1000's acre-feet) Without Conservation	Storage Required (1000's acre-feet) With Conservation
O[illegible]	15 ppt [illegible] mouth Choptank River (PY[illegible] 1/ w/o Conditions)	1,360	-	-	ALL	0	0
	Average [illegible] ppt below [illegible] Choptank River	1,510	210	[illegible]	ALL	1,262	1,153
	15 ppt below Barren Island ([illegible] 4/)	1,[illegible]	633	39	ALL	[illegible],313	2,363
T[illegible]	5 ppt at Tolchester [illegible] 0.5 ppt [illegible]	FRE/OLD 195/3[illegible]0	-	-	ALL	0	0
	5 ppt [illegible] Sassafras River [illegible]	[illegible]	1075	7/1	[illegible]	[illegible]	[illegible]
Submerged Aquatic Vegetation	12 ppt [illegible] below mouth Choptank River [illegible] W/O Conditions	[illegible]		-	[illegible]	0	0
	[illegible] ppt below [illegible] mouth Patuxent River ([illegible])	1,360	190	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

TABLE B-III-5 (Cont'd)

PHASE I PLAN FORMULATION
LONG TERM AVERAGE PLANS

Species/ Resource	Salinity Goal	Total Habitat Km^2	Habitat Change (from FD) Km^2	Habitat Change (from FD) %	Action Season	Storage Required (1000's acre-feet) Without Conservation	Storage Required (1000's acre-feet) With Conservation
"	12 ppt below mouth Potomac River	1,520	500	49	SP	1,052	1,004
Sea Nettle Control	7 ppt below Baltimore Harbor (FA = W/O Conditions)	4,960	-	-	SP	0	0
"	2 ppt reduction of BA in Midbay offshore of Blood Point	4,590	-370	-7	SP	2,490	2,442
Soft Clam	14 ppt above mouth Choptank River (FA = W/O Condition)	900	-	-	SU	0	0
"	14 ppt below mouth Choptank River (Base Average)	780	350	95	SU	601	[illegible]
Bankia & Teredo Control	11 ppt above West River (Future Average = W/O Condition)	6,400 (slips affected above BA)	-		SU	0	0
"	11 ppt below Herring Bay (Base Average	3,530 (no. of slips)	-3030	-49	SU	[illegible]	[illegible]

TABLE B-III-3 (cont'd)

PHASE I PLAN FORMULATION
LONG TERM AVERAGE PLANS

Species/ Resource	Salinity Goal	Total Habitat Km^2	Habitat Change (from FD) Km^2	Habitat Change (from FD) %	Action Season	Storage Required (1000's acre-feet) Without Conservation	Storage Required (1000's acre-feet) With Conservation
Macoma	13 pt below Choptank River (Future Average)	1,480		-	Fall	0	0
"	13 ppt below Point No Point (Base Average)	2,220	740	50	Fall	605	[illegible]

EVALUATION OF PHASE I PLANS

Early in the evaluation process, the feasibility of accomplishing "long-term average" plans through the use of storage became doubtful. Practical considerations arose regarding the monitoring necessary to determine release schedules to accomplish long-term average goals. Thus, except for conservation plans, which would directly reduce future consumptive losses, all long-term average flow supplemention plans were dropped. Conservation was looked at more closely in later iterations of plan formulation.

Inspection of the quantities of storage shown on Table B-III-2 reveals that substantial amounts of water would be needed to provide protection beyond Base Drought levels. For example, the Base Average Plan for oysters specifies maintenance of the 15 ppt isohaline below South Marsh Island in Tangier Sound. A minimum of 8.2 million acre-feet of storage would be needed to accomplish this goal. Total estimated reasonable storage in the Susquehanna Basin is only 1.2 million acre-feet. Thus, protection for oysters at Base Average levels during a recurrence of the Future Drought is seen as extremely unlikely.

A similar conclusion was made for the other organisms considered in preliminary planning (SAV, soft clam, Bankia, Macoma, and the oligohaline/tidal freshwater zone). The 1.2 million acre-feet of storage available on the Susquehanna would be sufficient to alleviate only consumptive losses. Therefore, only Base Drought levels of protection can be provided.

It should be noted, however, that variations in salinity that occur about the long-term average are not necessarily detrimental. The variation in salinity is an essential component in the natural functioning of Chesapeake Bay. Also, it has only been during extreme drought events that high salinities have been specifically identified as multi-resource problems. In the case of oysters, however, the effects of MSX and dermo under all conditions of freshwater inflow are of special concern. Further penetration of these disease organisms into the Bay should be prevented if at all possible. But, this should not be accomplished at the expense of upsetting the balance of nature. Since the maintenance of variations in freshwater inflow had previously been adopted as a major constraint in the formulation of plans, the major thrust of the reservoir alternatives became restricted to a volume of storage equivalent to that required to make up for the impact of consumptive losses, or, at most, a small enhancement of Base Drought conditions.

A more in-depth look within this range of feasible storage is provided for the entire drainage basin in Phase II of plan formulation.

CHAPTER IV

PHASE II FLOW SUPPLEMENTATION ALTERNATIVES

Based on the results of preliminary plan screening for the Susquehanna River, a much more restricted array of drought related salinity criteria and storage requirements was pursued in this phase of plan formulation. The scope of investigation was expanded to encompass the entire estuary. Also, the possibilities of conservation were explored. Following two discreet iterations of screening, this chapter concludes with the identification of the most promising drought storage and conservation plans, and detailed evaluations of each.

STEERING COMMITTEE INPUT

Prior to initiation of Phase II of plan formulation, inputs were sought from the Chesapeake Bay Study Steering Committee relative to the results of Phase I. Technical assumptions, criteria, procedures and conclusions were presented to the committee for review. In general, the committee endorsed the planning objectives, salinity criteria and plan formulation assumptions. Concerns were expressed, however, relative to the storage volumes required to achieve the stated goals. Comments offered by the committee relevant to plan development and evaluation criteria for each species include:

Oysters:

- o Late spring and summer are more appropriate than spring alone for control of MSX — 15 ppt is the appropriate average salinity goal to control MSX.

- o Oysters can develop some degree of resistance to MSX, but the uncertainity regarding this phenomenon is such that it should not be included as a plan formulation factor.

- o Oyster spat set should also be considered in evaluating plans.

Oligohaline Zone:

- o All seasons are of importance, the priority order being spring, summer, fall, winter.

- o The tidal freshwater zone is also important, and should not be forgotten in plan development or evaluation.

Low Salinity SAV:

- o The low salinity varieties are a most important food source for waterfowl

- o Potential reductions in high salinity SAV are insignificant compared with the potential net advantage of enhancing low salinity varieties.

- o Spring is important for root and seed propagation; but, summer is important for maintenance of plant beds for juvenile fish, crabs, etc. Therefore, both should be considered.

Sea Nettle:

- o The importance of this species is such that it does not rate a specific planning focus, but should be retained for evaluation of effects on recreation.

Bankia & Teredo

- o Potential damages due to these species are documented historically and their retention is thus warranted. Their importance, however, does not warrant a specific planning focus.

In addition to these species-specific points, the Committee prioritized the Corps major planning objectives:

Priority 1 -	Oysters Oligohaline Zone Tidal Freshwater Zone
Priority 2 -	Low-salinity SAV Soft Clam Macoma
Priority 3 -	Bankia & Teredo Sea Nettle

The committee also recommended that:

- o The location of valued habitats be confirmed
- o Consumptive losses be the major factor of focus in low flow planning
- o Emphasis be placed on maintenance of the variability of seasonal inflows

PLAN DEVELOPMENT

The planning focus for Phase II was expanded to include the next four most prominent Bay tributaries (the Potomac, Rappahannock, James and York Rivers). The changes in important season designation for certain of the species or species groups and other recommendations of the Steering Committee, were incorporated into the criteria as were the Phase I findings concerning reasonable storage and implementability. Also, the seasonal commonality among certain of the species was recognized. This led to the development of plans from a seasonal perspective.

Early in this phase, reservoir storage and permanent conservation in the Upper Western Shore tributaries, and in other important rivers such as the Choptank, Chester and Patuxent, were eliminated from further consideration. It was evident that increases in habitat from either of these measures would be difficult to distinguish in the Bay, and would be too small to produce meaningful benefits. Thus, storage and permanent types of conservation were addressed in detail only for the Susquehanna, Potomac, James, Rappahannock and York Rivers in Phase II of plan development.

Drought emergency measures were also eliminated from further consideration as an independent alternative. The decision to do this stemmed from insights gained in developing the methodology for computing reservoir storage. In that work, it was found

that it takes from 3 to 5 months for the Bay salinities to fully reflect a change in freshwater inflow. This was called antecedent time. Emergency drought measures are short-term use restrictions which are practical only during summer and fall—a period whose length approximate antecedent times. In addition, the savings in consumptive losses associated with this alternative would be small and the measure would be difficult to implement and enforce in an area as large as the Chesapeake Bay Basin. Emergency drought measures do, however, have some potential for reducing the amount of reservoir storage required. This is demonstrated in the conservation and drought emergency measures section in Chapter II.

Species selected for Phase II plan formulation were restricted to those ranked priorities "one" and "two" by the Chesapeake Bay Steering Committee. Thus, sea nettle and the wood borers (Bankia and Teredo) were deleted from consideration. They were included, however, in evaluations of the most promising plans.

The above considerations resulted in the specification of 16 plans for each major tributary (four for each of four seasons). These plans are shown in Tables B-IV-1 through 5. Each seasonal designation (SP=Spring, SU=Summer, FA=Fall, WI=Winter) is followed by the numerical designations "1" through "4" which refer to the following goals:

1— No Action: equivalent to the Future Drought inflows and salinities

2— Conservation: represents inflows and salinities accompanying a medium level conservation plan (storage volumes are the amounts required in lieu of conservation)

3— Base Drought: equivalent to the Base Drought inflows and salinities

4— Base Drought Enhancement: represents a condition one-half way between Base Drought and Future Average.

The storage volume required to attain each of these levels for each season are shown in the tables for each river. These storage volumes include allowances for both maintenance of target salinities during the season of concern and satisfaction of antecedent inflow requirements. Also the volumes are sufficient to allow releases in two consecutive years to offset the effects of an assumed 3-year drought event. The derivation of these storages is presented in Attachment C. It should be noted that no sites were identified in the York River Basin. The reasonable storage is therefore zero. It was decided, however, that Table B-IV-5 should be displayed for informational purposes.

For each river that was investigated, only those species or species groups that were important in that river were evaluated. Thus, since Macoma populations are significant only in the Main Bay, the Potomac and Rappahannock Rivers, its habitat information is presented only for those rivers. Table B-IV-6 arrays the species being evaluated for each river. This information is based on the comprehensive biological work done for this study as presented in Appendix A, Problem Identification, and additonal contact with the scientific community. Information shown in Tables B-IV-1 through 5, describing the plans, includes: 1) increase in habitat from the previous plan, 2) percent increase in habitat from the previous plan.

TABLE B-IV-1

SUSQUEHANNA RIVER - MAIN BAY HABITATS

EFFECTS OF PLANS ON MAJOR RESOURCES DURING DROUGHT CONDITIONS

PLAN	STORAGE REQUIREMENTS (1,000 Ac-Ft)	OYSTERS HABITAT (km²)	OYSTERS CHANGE IN HABITAT (km²)	OYSTERS CHANGE IN HABITAT (%)	OLIGOHALINE ZONE HABITAT (km²)	OLIGOHALINE ZONE CHANGE IN HABITAT (km²)	OLIGOHALINE ZONE CHANGE IN HABITAT (%)	TIDAL FRESHWATER ZONE HABITAT (km²)	TIDAL FRESHWATER ZONE CHANGE IN HABITAT (km²)	TIDAL FRESHWATER ZONE CHANGE IN HABITAT (%)
SPRING										
No Action (1)	---				760	---	--	125	---	--
Conservation (2)	190-250				770	10	1	130	5	6
Base Drought (3)	850-1140				830	60	8	157	27	21
Base Drought Enh (4)	[illegible]				950	120	14	205	48	31
SUMMER										
No Action (1)	---	450	---	--	120	---	--	29	---	--
Conservation (2)	210-270	525	75	17	135	15	12	40	11	38
Base Drought (3)	920-1240	870	345	66	210	75	56	90	50	125
Base Drought Enh (4)	[illegible]	1120	250	29	410	200	95	120	30	33
FALL										
No Action (1)	---				100	---	--	15	---	--
Conservation (2)	210-270				115	15	15	15	0	0
Base Drought (3)	920-1210				185	70	61	17	2	13
Base Drought Enh (4)	[illegible]				190	5	3	55	38	224
WINTER										
No Action (1)	---				200	---	--	46	---	--
Conservation (2)	190-260				200	0	0	51	5	11
Base Drought (3)	860-1180				200	0	0	87	36	71
Base Drought Enh (4)	[illegible]				430	230	115	130	43	49

PLAN	LOW SALINITY SAV HABITAT (km²)	LOW SALINITY SAV CHANGE IN HABITAT (km²)	LOW SALINITY SAV CHANGE IN HABITAT (%)	SOFT CLAM HABITAT (km²)	SOFT CLAM CHANGE IN HABITAT (km²)	SOFT CLAM CHANGE IN HABITAT (%)	MACOMA HABITAT (km²)	MACOMA CHANGE IN HABITAT (km²)	MACOMA CHANGE IN HABITAT (%)
SPRING									
No Action (1)	645	---	--						
Conservation (2)	655	10	2						
Base Drought (3)	695	40	6						
Base Drought Enh (4)	850	155	22						
SUMMER									
No Action (1)	390	---	--	1	---	--			
Conservation (2)	395	5	1	15	14	1400			
Base Drought (3)	425	30	8	70	55	367			
Base Drought Enh (4)	540	115	27	120	50	71			
FALL									
No Action (1)							755	---	--
Conservation (2)							815	60	8
Base Drought (3)							1105	290	36
Base Drought Enh (4)							[illegible]	155	14
WINTER									
No Action (1)									
Conservation (2)									
Base Drought (3)									
Base Drought Enh (4)									

TABLE B-IV-2

POTOMAC RIVER

EFFECTS OF PLANS ON MAJOR RESOURCES DURING DROUGHT CONDITIONS

PLAN	STORAGE REQUIREMENTS (1,000 Ac-Ft)	OYSTERS HABITAT (km²)	OYSTERS CHANGE IN HABITAT (km²)	OYSTERS CHANGE IN HABITAT (%)	OLIGOHALINE ZONE HABITAT (km²)	OLIGOHALINE ZONE CHANGE IN HABITAT (km²)	OLIGOHALINE ZONE CHANGE IN HABITAT (%)	TIDAL FRESHWATER ZONE HABITAT (km²)	TIDAL FRESHWATER ZONE CHANGE IN HABITAT (km²)	TIDAL FRESHWATER ZONE CHANGE IN HABITAT (%)	LOW SALINITY SAV HABITAT (km²)	LOW SALINITY SAV CHANGE IN HABITAT (km²)	LOW SALINITY SAV CHANGE IN HABITAT (%)	SOFT CLAM HABITAT (km²)	SOFT CLAM CHANGE IN HABITAT (km²)	SOFT CLAM CHANGE IN HABITAT (%)	MACOMA HABITAT (km²)	MACOMA CHANGE IN HABITAT (km²)	MACOMA CHANGE IN HABITAT (%)
SPRING																			
No Action (1)	---				145	---	--	110	---	--	230	---	--						
Conservation (2)	36-48				140	-5	-3	115	5	5	240	10	4						
Base Drought (3)	370-500				120	-20	-14	145	30	26	310	70	29						
Base Drought Enh (4)	[illegible]				290	170	142	195	50	34	345	35	11						
SUMMER																			
No Action (1)	---	295	---	--	150	---	--	15	---	--	150	---	--	1	---	--			
Conservation (2)	48-60	310	15	5	155	5	3	20	5	33	160	10	7	2	1	100			
Base Drought (3)	440-560	390	80	26	170	15	10	41	21	105	205	45	28	9	7	350			
Base Drought Enh (4)	[illegible]	480	90	23	195	25	15	70	29	71	280	75	37	14	5	56			
FALL																			
No Action (1)	---				47	---	--	2	---	--							120	---	--
Conservation (2)	48-60				47	0	0	5	3	150							160	40	33
Base Drought (3)	450-5[illegible]				47	0	0	20	15	300							375	215	134
Base Drought Enh (4)	[illegible]				110	63	134	35	15	75							430	55	15
WINTER																			
No Action (1)	---				43	---	--	2	---	--									
Conservation (2)	36-56				44	1	2	4	2	100									
Base Drought (3)	390-540				55	11	25	17	13	325									
Base Drought Enh (4)	[illegible]				130	75	136	85	68	400									

TABLE B-IV-3

JAMES RIVER

EFFECTS OF PLANS ON MAJOR RESOURCES DURING DROUGHT CONDITIONS

PLAN	STORAGE REQUIREMENTS (1,000 Ac-Ft)	OYSTERS HABITAT (km^2)	OYSTERS CHANGE IN HABITAT (km^2)	OYSTERS CHANGE IN HABITAT (%)	OLIGOHALINE ZONE HABITAT (km^2)	OLIGOHALINE ZONE CHANGE IN HABITAT (km^2)	OLIGOHALINE ZONE CHANGE IN HABITAT (%)	TIDAL FRESHWATER ZONE HABITAT (km^2)	TIDAL FRESHWATER ZONE CHANGE IN HABITAT (km^2)	TIDAL FRESHWATER ZONE CHANGE IN HABITAT (%)	LOW SALINITY SAV HABITAT (km^2)	LOW SALINITY SAV CHANGE IN HABITAT (km^2)	LOW SALINITY SAV CHANGE IN HABITAT (%)	SOFT CLAM HABITAT (km^2)	SOFT CLAM CHANGE IN HABITAT (km^2)	SOFT CLAM CHANGE IN HABITAT (%)	MACOMA HABITAT (km^2)	MACOMA CHANGE IN HABITAT (km^2)	MACOMA CHANGE IN HABITAT (%)
SPRING														NO SIGNIFICANT AMOUNT IN JAMES RIVER			NO SIGNIFICANT AMOUNT IN JAMES RIVER		
No Action (1)	---				130	---	--	69	---	--	135	---	--						
Conservation (2)	2-3				130	0	0	69	0	0	135	0	0						
Base Drought (3)	180-220				107	-21	-18	93	24	35	126	-9	-7						
Base Drought Enh (4)	[illegible]				110	3	3	126	33	35	146	20	16						
SUMMER																			
No Action (1)	---	7	---	--	82	---	--	47	---	--	91	---	--						
Conservation (2)	8	7	0	0	82	0	0	49	2	4	91	0	0						
Base Drought (3)	200-240	15	8	114	82	0	0	81	32	65	91	0	0						
Base Drought Enh (4)	[illegible]	42	27	180	86	5	6	91	10	12	105	14	15						
FALL																			
No Action (1)	---				70	---	--	6	---	--									
Conservation (2)	4-8				70	0	0	6	0	0									
Base Drought (3)	200-240				61	-9	-13	20	14	233									
Base Drought Enh (4)	[illegible]				67	6	10	50	30	150									
WINTER																			
No Action (1)	---				76	---	--	12	---	--									
Conservation (2)	2-3				76	0	0	12	0	0									
Base Drought (3)	180-220				76	0	0	29	17	142									
Base Drought Enh (4)	[illegible]				86	10	13	76	47	162									

TABLE B-IV-4

RAPPAHANNOCK RIVER

EFFECTS OF PLANS ON MAJOR RESOURCES DURING DROUGHT CONDITIONS

PLAN	STORAGE REQUIREMENTS (1,000 Ac-Ft)	OYSTERS HABITAT (km²)	OYSTERS CHANGE IN HABITAT (km²)	OYSTERS CHANGE IN HABITAT (%)	OLIGOHALINE ZONE HABITAT (km²)	OLIGOHALINE ZONE CHANGE IN HABITAT (km²)	OLIGOHALINE ZONE CHANGE IN HABITAT (%)	TIDAL FRESHWATER ZONE HABITAT (km²)	TIDAL FRESHWATER ZONE CHANGE IN HABITAT (km²)	TIDAL FRESHWATER ZONE CHANGE IN HABITAT (%)	LOW SALINITY SAV HABITAT (km²)	LOW SALINITY SAV CHANGE IN HABITAT (km²)	LOW SALINITY SAV CHANGE IN HABITAT (%)	SOFT CLAM HABITAT (km²)	SOFT CLAM CHANGE IN HABITAT (km²)	SOFT CLAM CHANGE IN HABITAT (%)	MACOMA HABITAT (km²)	MACOMA CHANGE IN HABITAT (km²)	MACOMA CHANGE IN HABITAT (%)
SPRING																			
No Action (1)	---				23	---	--	34	---	--	110	---	--	NO SIGNIFICANT AMOUNT IN RAPPAHANNOCK RIVER					
Conservation (2)	5-7				24	1	4	34	0	0	110	0	0						
Base Drought (3)	42-56				31	7	29	31	-3	-9	111	1	1						
Base Drought Enh (4)	54-[illegible]				55	24	77	40	9	29	145	34	31						
SUMMER																			
No Action (1)	---	42	---	--	32	---	--	8	---	--	78	---	--						
Conservation (2)	5-7	45	3	7	33	1	3	8	0	0	80	2	3						
Base Drought (3)	44-58	65	[illegible]	44	[illegible]	4	12	9	1	12	92	12	15						
Base Drought Enh (4)	[illegible]	105	[illegible]	62	37	0	0	21	12	133	125	33	36						
FALL																			
No Action (1)	---				17	---	--	3	---	--							2[illegible]	---	--
Conservation (2)	6-8				18	1	6	3	0	0							30	6	25
Base Drought (3)	44-58				24	6	33	3	0	0							70	40	33
Base Drought Enh (4)	[illegible]				29	5	21	12	9	300							85	15	21
WINTER																			
No Action (1)	---				8	---	--	2	---	--									
Conservation (2)	6-8				9	1	12	2	0	0									
Base Drought (3)	42-56				18	9	1[illegible]	3	1	50									
Base Drought Enh (4)	[illegible]				30	1[illegible]	67	[illegible]	[illegible]	666									

TABLE B-IV-5

YORK RIVER

EFFECTS OF PLANS ON MAJOR RESOURCES DURING DROUGHT CONDITIONS

PLAN	STORAGE REQUIREMENTS (1,000 Ac-Ft)	OYSTERS			OLIGOHALINE ZONE			TIDAL FRESHWATER ZONE			LOW SALINITY SAV			SOFT CLAM			MACOMA		
		HABITAT (km²)	CHANGE IN HABITAT (km²)	CHANGE IN HABITAT (%)	HABITAT (km²)	CHANGE IN HABITAT (km²)	CHANGE IN HABITAT (%)	HABITAT (km²)	CHANGE IN HABITAT (km²)	CHANGE IN HABITAT (%)	HABITAT (km²)	CHANGE IN HABITAT (km²)	CHANGE IN HABITAT (%)	HABITAT (km²)	CHANGE IN HABITAT (km²)	CHANGE IN HABITAT (%)	HABITAT (km²)	CHANGE IN HABITAT (km²)	CHANGE IN HABITAT (%)
SPRING														NO SIGNIFICANT AMOUNT IN YORK RIVER			NO SIGNIFICANT AMOUNT IN YORK RIVER		
No Action (1)	---				15	---	--	4	-	--	61	--	--						
Conservation (2)	13-15				15	0	0	4	0	0	61	0	0						
Base Drought (3)	64-76				15	0	0	4	0	0	63	2	3						
Base Drought Enh (4)	[illegible]				30	15	100	5	1	25	87	24	38						
SUMMER																			
No Action (1)	---	13	---	--	11	---	--	2	-	--	42	--	--						
Conservation (2)	14-17	14	1	8	13	2	18	2	0	0	43	1	2						
Base Drought (3)	66-80	16	2	14	26	13	100	3	1	50	47	4	9						
Base Drought Enh (4)	[illegible]	35	19	119	26	0	0	3	0	0	53	6	13						
FALL																			
No Action (1)	---				15	---	--	0	-	--									
Conservation (2)	14-17				16	1	7	0	0	0									
Base Drought (3)	66-80				20	4	25	2	2	[illegible]									
Base Drought Enh (4)	380-450				17	-3	-15	4	2	100									
WINTER																			
No Action (1)	---				17	---	--	2	-	--									
Conservation (2)	12-15				17	0	0	2	0	0									
Base Drought (3)	64-76				18	1	6	3	1	50									
Base Drought Enh (4)	[illegible]				30	[illegible]	67	4	1	33									

TABLE B-IV-6
PRIORITY RESOURCE AREAS

Species	Main Bay	Potomac	James	Rappahannock	York
Oyster	X	X	X	X	X
Oligohaline Zone	X	X	X	X	X
SAV	X	X	X	X	X
Soft Clam	X	X			
Maco. ıa Balthica	X	X		X	
Sea Nettle	X	X			
Bankia	X	X			

FIRST ITERATION EVALUATION

The criteria used in evaluation of the Phase II plans include:

1. Change in habitat—to be retained, a plan must provide at least a 25 percent incremental increase in habitat for one of the six major resources. This criterion was established to provide a vehicle for selecting from the array of alternatives those which have potential for being cost effective. It was based on the concensus judgement of the study team that changes in habitat less than 25 percent would not produce benefits sufficient to justify the cost of implementing the plan.

2. Required storage—the volume of storage required for a plan will not exceed that which has been defined as reasonable (See Table B-IV-7).

TABLE B-IV-7
COMPARISON OF LIMITING STORAGES
BY BASIN

	Five Percent of Average Annual Flow (acre-ft.)	Storage Potential (Reallocated Plus New) (acre-ft.)
Susquehanna	1,418,000	1,200,000 *
Potomac (8+9+10)	449,000	400,000 *
James (2+3+4)	370,000 *	1,115,000
Rappahannock	106,000 *	713,000
York	96,000	0 *

*Limiting value—assumed maximum reasonable storage available for Phase II formulation

The results of application of the adopted criteria are shown in Table B-IV-8, and are described further in the following section.

REFINEMENT OF PHASE II PLANS

The most productive flow supplementation plans from a single season perspective were identified in the previous section based on the criteria for reservoir storage availability and habitat protection. As can be seen, conservation proved beneficial in only the Susquehanna and Potomac Rivers. These conservation plans were retained as most promising alternatives.

As shown in Table B-IV-8, the maximum protection that can be provided by reservoir storage for any of the tributaries is at the Base Drought level. In the Susquehanna, the Base Drought plans for the summer, fall and winter survived the screening. In the Potomac, James, and Rappahannock Rivers, plans for all four seasons were retained.

Each of these storage plans is independent of the other and would require storage volumes approaching that considered reasonable. Because of this, only one seasonal plan could be implemented in each basin. No reservoir storage protection could be provided in the other seasons. But, each of the storages shown on Tables B-IV-1 through 5 include sufficient volumes to allow for the satisfaction of the antecedent flow requirements. In fact, these requirements make up over half of the storage volumes. It was noted that if a plan were developed that combined consecutive seasons, the antecedent storage requirements for the second season would already be met. In effect, releases of water from storage during the first season would satisfy the antecedent conditions for the second one.

It was not clear, however, whether single or multi-season plans would prove the most beneficial if cost effectiveness was considered. The refinement of alternatives was therefore addressed from two perspectives: 1) The selection of the single season plan for each basin that appears to be the most beneficial for habitat protection, and 2) The development and selection of multi-season plans.

Single Season Plans

The next iteration of Phase II screening was based on the previously described Steering Committee's priority ranking of the species. The analysis for each river is as follows.

Susquehanna River. The summer, fall and winter Base Drought level plans for the Susquehanna River were retained after the first iteration of Phase II screening. The summer plan provides significant increases in habitat for three priority 1 objectives (oysters, oligohaline zone and tidal freshwater zone) and one priority 2 species (soft clams). The fall plan increases the habitat of only two species, the priority 1 oligohaline zone and the priority 2 *Macoma*. The winter plan protects only the priority 1 tidal freshwater zone.

It is obvious that the summer plan provides the highest Base Drought level of benefits not only in terms of the number of species protected, but the value of them. There are, however, two additional factors to consider. The first is that oysters are by far the most severely impacted of the species. If at all possible, plans should address them. Only the summer plan does, and, second, summer ranks only behind spring as a critical season for the oligohaline and tidal freshwater zones.

TABLE B-IV-8

PHASE II SCREENING RESULTS

PLAN / RIVER	SPRING			SUMMER			FALL			WINTER		
	SP-2	SP-3	SP-4	SU-2	SU-3	SU-4	FA-2	FA-3	FA-4	WI-2	WI-3	WI-4
Susquehanna	H	H	S	tidal fresh soft clam	oyster olig. zone tidal fresh soft clam	S	H	oligo. zone *Macoma*	S	H	tidal fresh	S
Potomac	H	tidal fresh SAV	S	tidal fresh soft clam	oyster tidal fresh SAV soft clam	S	tidal fresh *Macoma*	tidal fresh *Macoma*	S	tidal fresh	oligo. zone tidal fresh	S
James	H	tidal fresh	S	H	oyster tidal fresh	S	H	tidal fresh	S	H	tidal fresh	S
Rappahannock	H	oligo. zone	S	H	oyster	S	H	*Macoma* oligo. zone	S	H	oligo. zone tidal fresh	S
York	H/S	H/S	S	H/S	S	S	H/S	S	S	H/S	S	S

NOTE: Species shown are those whose habitat change met the screening criteria.
Plan dropped because of: H = Insignificant increase in habitat
S = Storage requirement exceeds that considered reasonable.

Potomac River. All four Base Drought level plans survived the first iteration of Phase II planning for the Potomac River. Again, the summer plan proved to be the most beneficial. It provides habitat improvement for four species. Two of these (oysters and tidal freshwater zone) are high priorities. The remaining plans benefit only two species. As in the Susquehanna River, the presence of oysters in the summer plan and the importance of the season to the tidal freshwater zone, reinforced the decision to retain it for further consideration.

James River. The habitat of the tidal freshwater zone is significantly increased in all four plans for the James River. Only the summer plan, however, provides protection for an additional species, the oyster. In view of this, there is no question the summer plan is the most beneficial.

Rappahannock River. Unlike the Susquehanna, Potomac, and James, it was not immediately evident which of the plans is the most beneficial. The oyster, is protected only by the summer plan. On the other hand, the oligohaline zone is addressed in the other three plans, but not in the summer one. In an effort to gain better insight to the comparative value of the plans, the changes in habitat shown on Table B-IV-4 were reviewed in detail. It was found that habitat for the oyster increased 44 percent in the summer, the Macoma 33 percent in the fall, the tidal freshwater zone 71 percent in the winter and the oligohaline zone 29 percent in the spring, 33 percent in the fall and 100 percent in the winter. The 100 percent increase in the winter oligohaline zone combined with the 71 percent increase in the tidal freshwater zone would appear to make a compelling case for the selection of the winter plan; especially in view of the priority 1 ranking of these zones. However, winter is of lesser importance for both the oligohaline and tidal freshwater zones. On the other hand, the need for providing protection to the oyster is unquestioned. It was therefore decided that the summer plan should be the one retained.

Multiple Season Plans

The reservoir storage volumes required for multiple season plans are shown on Table B-IV-9, for three assumed levels of conservation (certain of the single-season plans are also shown for comparison). Because the summer plans provide the most benefits, only multi-season plans which included that season were considered. A comparison of the storage required for each of the multi-season plans, with that considered reasonable, reveals that only the plans for the Rappahannock and James Rivers are feasible without conservation. In the Susquehanna River, permanent conservation measures must be instituted to accomplish the summer-fall (SUFA-3) plan. Even with drought emergency measures, the multi-season storage required in the Potomac River exceeds that considered reasonable. Multi-season plans have therefore been dropped from further consideration on the Potomac.

MOST PROMISING FLOW SUPPLEMENTATION ALTERNATIVES

In previous sections of this appendix, flow supplementation alternatives were reviewed in detail. Each plan was analyzed relative to the increases in habitat produced, as well as the value of that habitat and the amount of storage required to achieve the plan formulation goals. From this work, the most promising conservation and reservoir storage alternatives were identified. These are:

Conservation:	Susquehanna River Potomac River	
Reservoir Storage:	Susquehanna River -	Summer Base Drought Level Summer-Fall Base Drought Level
	Potomac River -	Summer Base Drought Level
	James River -	Summer Base Drought Level Summer-Fall Base Drought Level Spring-Summer Base Drought Level
	Rappahannock River -	Summer Base Drought Level Summer-Fall Base Drought Level Spring-Summer Base Drought Level

TABLE B-IV-9

STORAGE REQUIREMENTS
SINGLE AND MULTI-SEASON PLANS

River	Promising Seasonal Plans	Period of Action, Incl. Season of Concern (Days) Low	Period of Action, Incl. Season of Concern (Days) High	Storage Required For Two Consecutive Years of Releases (1000's acre-ft): No conservation Low	No conservation High	with Conservation Low	with Conservation High	With Conservation & Drought Emergency Low	With Conservation & Drought Emergency High	Assumed Reasonable Storage Available (1000's acre-ft)
Susquehanna	SU-3	180	240	920	1200	710	930	650	870	1200
	FA-3	180	240	920	1210	710	940	590	820	
	SUFA-3	270	330	1360	1630	1050	1270	930	1150	
Potomac	SP-3	180	240	370	500	330	450	330	430	400
	SU-3	180	240	440	560	390	500	360	470	
	FA-3	180	240	450	570	400	510	350	450	
	SPSU-3	270	330	630	760	560	690	550	650	
	SUFA-3	270	330	[illegible]	760	570	680	[illegible]	630	
James	SP-3	150	180	160	220	180	220	170	200	370*
	SU-3	150	180	[illegible]	240	190	230	170	210	
	FA-3	150	180	[illegible]	240	[illegible]	[illegible]	170	180	
	SPSU-3	240	270	310	350	290	340	[illegible]	300	
	SUFA-3	240	270	310	350	300	330	250	290	
Rappahannock	SP-3	180	240	40	60	35	50	35	50	105*
	SU-3	180	240	45	60	40	50	[illegible]	45	
	FA-3	180	240	45	60	40	50	40	45	
	SPSU-3	270	330	65	80	60	70	50	60	
	SUFA-3	270	330	65	80	60	70	50	60	

*Limited by 2 percent of average annual flow criteria (see Chapter IV for discussion).

CHAPTER V

MOST PROMISING ALTERNATIVES

The plan formulation process yielded the following most promising alternative solutions for preventing or ameliorating the adverse effects of reduced freshwater inflows. These include:

Flow Supplementation Measures

Reservoir Storage (new and reallocable)
Conservation (general, year around)
Restricted Growth

Chesapeake Bay Management Measures

Oyster bed restoration
Finfish restocking
Catch restrictions

Of these, the first two types of flow supplementation alternatives, reservoir storage and conservation, have been analyzed in detail. On the other hand, no in-depth analyses were done for the growth restriction or Chesapeake Bay management measures. In the case of restricted growth, information and precedences for defining and evaluating alternatives were not available. Similarly, while they are felt to be generally beneficial, detailed analysis of specific Bay management measures was felt to be beyond the scope of this study. In any case, the data requirements for meaningful plan development and evaluation is severely lacking for most of these types of measures.

RESERVOIR STORAGE

Reservoir storage is a plan designed to supplement freshwater inflows in the Bay's major rivers during a drought. In previous chapters, it was determined that storages required to entirely offset the Future Drought event (i.e., consumptive losses plus drought) would not only require storage far in excess of that assumed to be feasible, but may not be particularly desirable. For example, on the Susquehanna River more than 10 million acre-feet of storage is estimated to be required to return Future Drought levels to Base Average levels inflow for two consecutive years. Only 1.2 million acre-feet of storage is estimated to be reasonable. Reservoir storage plans have thus been formulated to fully make up for consumptive losses during one or, possibly, two seasons during a drought.

The limitation on storage plans to approximately the magnitude of consumptive losses is not necessarily a disadvantage. While it would mean that Base Drought salinity conditions in the Bay would be allowed to occur, natural variability in salinity, both seasonally and from year to year, are part of the natural character of the estuary. In fact, it has only been during extreme drought events that high salinities have been specifically identified as multi-resource problems. An exception to this is the case of oysters. This species is of concern under all conditions of inflow.

The entire array of feasible storage plans is summarized in Table B-V-1. The storage volumes shown are those required during a Future Drought event to return the Bay to, and maintain it at, Base Drought salinities during one or two seasons. The volumes also are sufficient to allow releases from storage, during the appropriate seasons, for two consective years.

All of the most promising storage plans are attainable with storage alone, with the exception of the Susquehanna Summer-Fall Base Drought Plan (SUFA-3), and the Potomac SU-3 Plan. Each of these would require a coincident conservation plan to be in effect in order to meet salinity goals. The Susquehanna and Potomac Rivers thus appear to have the storage capability necessary to make up little more than the effects of consumptive losses during one or, at most, two consective seasons.

The James and Rappahannock Rivers, however, are shown to have potential storage sufficient to offset somewhat more than just consumptive losses. The availability of this additional water may have benefits worthy of further consideration in future, more in-depth, analyses. This is especially true as it relates to improved management of oysters. Oysters are of principal commercial importance in the James and Rappahannock Rivers.

Benefits associated with each of the identified most promising storage plans are displayed in Tables B-V-2 through 5. Listed across the top of each table are the most promising storage plans, and the "No Action" plan.

Environmental benefits are shown in terms of habitat change for each of the selected major resources used to define planning objectives for this study. A dash indicates the species or resource was not identified as a priority in that river. Some of the habitat increases are substantial, such as the increase from 29 Km^2 to 61 Km^2 for the tidal freshwater zone in the Main Bay (Susquehanna River) in summer. This plan changes the "impact ratio" (defined as the ratio of habitat for each plan to habitat available under Base Average Conditions) from 0.18 (82 percent reduction) to 0.56 (44 percent reduction). This is equivalent to a 210 percent increase in habitat for the tidal freshwater zone in summer.

Social and economic benefits associated with each of the identified most promising storage plans are also shown in Tables B-V-2 through 5. For example, summer plans improve habitat in the tidal freshwater and oligohaline zones. Since commercial fisheries and recreation activities in the Bay depend on the success of juvenile finfish in the oligohaline and tidal freshwater zones in summer, the benefits of increasing habitat in these areas is reflected in the commercial fishery and recreation accounts. Other benefits within the recreation category are shown for boating, swimming and waterfowl hunting. In some of the rivers in which priority resource problems were not identified, or in which significant habitat improvement does not occur (such as for boating or waterfowl hunting in the James River), the statement "No Benefits" appears.

Only the priority problem species were included in the categorized benefit analysis. The rest of the 57 selected study species were addressed under the "other species" column. This list of organisms is intended to indicate whether the changes due to any of the flow supplementation plans listed acress the top are beneficial or detrimental.

TABLE B-V-1
STORAGE REQUIREMENTS FOR MOST PROMISING STORAGE PLANS

River	Base Drought Plan	Storage Requirement for Two Consecutive Years of Releases (1000's acre-feet) Without Conservation Low	High	With Conservation Low	High	Assumed Reasonable Storage (1000 ac-ft)
Susquehanna	SU-3	920	1200	710	930	1200
	SUFA-3	1360	1630	1050	1270	1200
Potomac	SU-3	440	560	390	500	400
James	SU-3	200	240	190	230	370
	SPSU-3	310	350	300	340	370
	SUFA-3	310	350	300	340	370
Rappahannock	SU-3	45	60	40	50	106
	SPSU-3	65	80	60	70	106
	SUFA-3	65	80	60	70	106

TABLE B-V-2

BENEFITS OF SUSQUEHANNA RIVER STORAGE PLANS DURING DROUGHT CONDITIONS

	No Action (Future Drought)	Summer Base Drought Level	Summer-Fall Base Drought Level
STORAGE REQUIREMENTS			
Without Conservation	-	920,000 - 1,200,000	1,360,000 - 1,630,000
With Conservation	-	710,000 - 930,000	1,050,000 - 1,270,000
With Cons. & Drought Emer.	-	650,000 - 870,000	930,000 - 1,150,000

PROBLEM SPECIES		No Action: Habitat (KM^2)	No Action: Impact Ratio	Summer: Change in Habitat (KM^2)	Summer: Change in Habitat (%)	Summer: Impact Ratio	Summer-Fall: Change in Habitat (KM^2)	Summer-Fall: Change in Habitat (%)	Summer-Fall: Impact Ratio
Oysters	(Summer)	450	.24	420	93	.46	420	93	.46
Oligohaline Zone Species	(Spring)	760	.74	0	0	.74	0	0	.74
	(Summer)	120	.19	90	75	.33	90	75	.33
	(Fall)	100	.45	0	0	.45	90	90	.85
	(Winter)	200	.31	0	0	.31	0	0	.31
Tidal Freshwater Zone Species	(Spring)	125	.57	0	0	.57	0	0	.57
	(Summer)	29	.18	61	210	.56	61	210	.56
	(Fall)	15	.13	0	0	.13	2	13	.14
	(Winter)	46	.25	0	0	.25	0	0	.25
Submerged Aquatic Vegetation	(Spring)	645	.54	0	0	.54	0	0	.54
	(Summer)	390	.57	35	9	.62	35	9	.62
Soft Clam	(Summer)	1	0	69	6900	.15	69	6900	.15
Macoma	(Fall)	755	.34	0	0	.34	350	46	.50

	No Action (Future Drought)	Summer Base Drought Level	Summer-Fall Base Drought Level
COMMERCIAL FISHERY	No Benefits	Potential increased harvest due to significant increases in habitat of oysters, soft clams, and juvenile finfish	Potential increased harvest due to significant increases in habitat of oysters, soft clams and juvenile finfish
RECREATION			
Boat slips exposed to *Bankia/Teredo*	No Benefits	Significantly reduced	Significantly reduced
Swimming	No Benefits	Slight reduction in density of nettles	Slight reduction in density of nettles
Sport Fishing	No Benefits	Potential increase in preferred species due to significant increase in habitat of juvenile finfish	Potential increase in preferred species due to significant increase in habitat of juvenile finfish
Hunting (Waterfowl)	No Benefits	Potential increase in duck populations due to slight increase in food for ducks (SAV)	Potential increase in duck populations due to significant increase in food for canvasback (*Macoma*) and slight increase in food for other ducks (SAV)
Water Users	No Benefits	Slight benefit in summer	Slight benefits in summer and fall
Other Tributaries	No Benefits	Will generally reduce the salinity at the mouth of each tributary in summer	Will generally reduce the salinity at the mouth of each tributary in summer and fall
Other Species	No Benefits	BENEFICIAL Summer: Prorocentrum minimum Chrysora quinquecirrha (Polyp) Rangia cuneata Fall: None	DETRIMENTAL Summer: Polyhaline Phytoplankton Ruppia maritima Mnemiopsis leidyi Chrysaora quinquecirrha (medusa) Acartia tonsa Evadne tergestina Streblospio bendicti Urosalpinx cinerea Menidia menidia Mercenaria mercenaria Brevoortia tyrannus-Adult Micropogonias undulatus-Adult Leiostomus xanthurus-Adult Heteromastus filiformis Zostera marina Balanus improvisus Anchoa mitchilli Fall: Mulinia lateralis

TABLE B-V-3

BENEFITS OF POTOMAC RIVER STORAGE PLANS DURING DROUGHT CONDITIONS

		No Action (Future Drought)		Summer Base Drought Level		
STORAGE REQUIREMENTS						
Without Conservation		-		440,000 - 560,000		
With Conservation		-		390,000 - 500,000		
With Cons. & Drought Emer.		-		360,000 - 470,000		
PROBLEM SPECIES		Habitat (KM^2)	Impact Ratio	Change in Habitat (KM^2)	(%)	Impact Ratio
Oysters	(Summer)	295	.44	95	32	.59
Oligohaline Zone Species	(Spring)	145	.28	0	0	.28
	(Summer)	150	.94	20	13	1.06
	(Fall)	47	.23	0	0	.23
	(Winter)	43	.24	0	0	.24
Tidal Freshwater Zone Species	(Spring)	110	.42	0	0	.42
	(Summer)	15	.10	26	173	.28
	(Fall)	2	.03	0	0	.03
	(Winter)	2	.02	0	0	.02
Submerged Aquatic Vegetation	(Spring)	230	.51	0	0	.51
	(Summer)	150	.41	55	37	.56
Soft Clam	(Summer)	1	0	8	800	.05
Macoma	(Fall)	120	.20	0	0	20

	No Action (Future Drought)	Summer Base Drought Level	
COMMERCIAL FISHERY	No Benefits	Potential increased harvest due to significant increases in habitat of oysters, soft clams, and juvenile finfish	
RECREATION			
Boat slips exposed to *Bankia/Teredo*	No Benefits	Significantly reduced	
Swimming	No Benefits	Slight reduction in density of nettles	
Sport Fishing	No Benefits	Potential increase in preferred species due to significant increase in habitat of juvenile finfish	
Hunting (Waterfowl)	No Benefits	Potential increase in duck populations due to a significant increase in food for ducks (SAV)	
Water Users	No Benefits	Slight benefit in summer	
Other Tributaries	No Benefits	Will generally reduce the salinities in the main bay near the mouth of the Potomac during the summer	
Other Species	No Benefits	**Beneficial** Summer: Prorocentrum minimum Chrysaora quinquecirrha (Polyp) Heteromastus filiformis	**Detrimental** Summer: Anchoa mitchilli Balanus improvisus Leiostomus xanthurus (Adult) Ruppia maritima Mnemiopsis leidyi Chrysaora quinquecirrha (Medusa) Acartia tonsa Streblospio benedicti Urosalpinx cinerea Menidia menidia Brevoortia tyrannus (Adult) Micropogonias undulatus Micropogonias undulatus (Adult)

TABLE B-V-4

BENEFITS OF JAMES RIVER STORAGE PLANS DURING DROUGHT CONDITIONS

		No Action (Future Drought)		Summer Base Drought Level			Spring-Fall Base Drought Level			Summer-Fall Base Drought Level		
STORAGE REQUIREMENTS												
Without Conservation		-		200,000 - 240,000			310,000 - 350,000			310,000 - 350,000		
With Conservation		-		190,000 - 230,000			300,000 - 340,000			300,000 - 340,000		
With Cons. & Drought Emer.		-		170,000 - 210,000			280,000 - 320,000			250,000 - 290,000		
PROBLEM SPECIES		Habitat (KM^2)	Impact Ratio	Change in Habitat (KM^2)	Change in Habitat (%)	Impact Ratio	Change in Habitat (KM^2)	Change in Habitat (%)	Impact Ratio	Change in Habitat (KM^2)	Change in Habitat (%)	Impact Ratio
Oysters	(Summer)	7	.09	8	114	.19	8	114	.19	8	114	.19
Oligohaline Zone Species	(Spring)	130	.99	0	0	.99	-23	-18	.82	0	0	.99
	(Summer)	82	.71	0	0	.71	0	0	.71	0	0	.71
	(Fall)	70	.89	0	0	.89	0	0	.89	-9	-13	77
	(Winter)	76	.86	0	0	.86	0	0	.86	0	0	.86
Tidal Freshwater Zone Species	(Spring)	69	.43	0	0	.43	24	35	.57	0	0	.43
	(Summer)	47	.42	34	72	72	34	72	.72	34	72	.72
	(Fall)	6	.07	0	0	07	0	0	.07	14	233	.23
	(Winter)	12	.08	0	0	08	0	0	.08	0	0	.08
Submerged Aquatic Vegetation	(Spring)	135	.78	0	0	.78	-9	-7	.73	0	0	.78
	(Summer)	91	.71	0	0	.71	0	0	.71	0	0	.71
Soft Clam	(Summer)	-	-	-	-	-	-	-	-	-	-	-
Macoma	(Fall)	-	-	-	-	-	-	-	-	-	-	-

	No Action (Future Drought)	Summer Base Drought Level	Spring-Fall Base Drought Level	Summer-Fall Base Drought Level
COMMERCIAL FISHERY	No Benefits	Potential increase in harvest due to significant increase in habitat of oysters & juvenile finfish	Potential increase in harvest due to moderate increase in spawning area and habitat of juvenile finfish, significant increase in habitat of oysters	Potential increase in harvest due to significant increase in habitat of oysters and juvenile finfish
RECREATION				
Boat slips exposed to Bankia/Teredo	No Benefits	No Benefits	No Benefits	No Benefits
Swimming	No Benefits	Slight reduction in density of nettles	Slight reduction in density of nettles	Slight reduction in density of nettles
Sport Fishing	No Benefits	Potential increase in preferred species due to significant increase in habitat of juvenile finfish	Potential increase in preferred species due to moderate increase in spawning area and habitat of juvenile finfish	Potential increase in preferred species due to significant increase in habitat of juvenile finfish
Hunting (Waterfowl)	No Benefits	No Benefits	No Benefits	No Benefits
Water Users	No Benefits	Slight benefit in summer	Slight benefit in spring and summer	Slight benefit in summer and fall
Other Tributaries	No Benefits	Will generally reduce the salinities in the main bay near the mouth of the James River during the summer	Will generally reduce the salinities in the main bay near the mouth of the James River during the spring and summer	Will generally reduce the salinities in the main bay near the mouth of the James River during the summer and fall
Other Species	No Benefits			

Other Species (all storage plans):

BENEFICIAL

Spring: Leptocheirus plumulosus
- Mesohaline Phytoplankton
- Acartia clausi

Summer: Prorocentrum minimum
- Chrysaora quinquecirrha-polyp
- Heteromastus filiformis
- Rangia cuneata

Fall: None

DETRIMENTAL

Spring: Polyhaline Phytoplankt
- Pedon polyphemoides
- Pectinaria gouldii
- Ampelisca abdita
- Zostera marina

Summer: Polyhaline Phytoplankt
- Ruppia maritima
- Mnemiopsis leidyi
- Chrysaora quinquecirrha - Adul
- Acartia tonsa
- Evadne tergestina
- Streblespio benedicti
- Urosalpinx cinerea
- Menidia menidia
- Brevoortia tyrannus - Adult
- Micropagonias undulatu - Adult
- Leisostamus xanthurus - Adult
- Zostera marina

Fall: Mulinia lateralis

TABLE B-V-5

BENEFITS OF RAPPAHANNOCK RIVER PLANS DURING DROUGHT CONDITIONS

		No Action (Future Drought)		Summer Base Drought Level			Spring-Summer Base Drought Level			Summer-Fall Base Drought Level		
STORAGE REQUIREMENTS												
Without Conservation		-		45,000 - 60,000			65,000 - 80,000			65,000 - 80,000		
With Conservation		-		40,000 - 50,000			60,000 - 70,000			60,000 - 70,000		
With Cons. & Drought Emer.		-		35,000 - 45,000			55,000 - 60,000			50,000 - 60,000		
PROBLEM SPECIES		Habitat (KM^2)	Impact Ratio	Change in Habitat (KM^2)	Change in Habitat (%)	Impact Ratio	Change in Habitat (KM^2)	Change in Habitat (%)	Impact Ratio	Change in Habitat (KM^2)	Change in Habitat (%)	Impact Ratio
Oysters	(Summer)	42	.24	23	55	.38	23	55	.38	23	55	.38
Oligohaline Zone Species	(Spring)	23	.30	0	0	.30	8	35	.41	0	0	.30
	(Summer)	32	.80	5	16	.93	5	16	.93	5	16	.93
	(Fall)	17	.50	0	0	.50	0	0	.50	7	41	.71
	(Winter)	8	.16	0	0	.16	0	0	.16	0	0	.16
Tidal Freshwater Zone Species	(Spring)	34	.68	0	0	.68	-3	-9	.62	0	0	.68
	(Summer)	8	.20	1	12	.23	1	12	.23	1	12	.23
	(Fall)	3	.14	0	0	.14	0	0	.14	0	0	.14
	(Winter)	2	.05	0	0	.05	0	0	.05	0	0	.05
Submerged Aquatic Vegetation	(Spring)	110	.70	0	0	.70	1	1	.70	0	0	.70
	(Summer)	78	.52	14	18	.62	14	18	.62	14	18	.62
Soft Clam	(Summer)	-	-	-	-	-	-	-	-	-	-	-
Macoma	(Fall)	24	.17	0	0	.17	0	0	.17	46	192	.48

	No Action (Future Drought)	Summer Base Drought Level	Spring-Summer Base Drought Level	Summer-Fall Base Drought Level
COMMERCIAL FISHERY	No Benefit	Potential increase in harvest due to significant increase in oyster habitat and moderate increase in habitat of juvenile finfish	Potential increase in harvest due to significant increase in oyster habitat and moderate increase in spawning area and habitat of juvenile finfish	Potential increase in harvest due to signifi cant increase in oyste habitat and moderate crease in habitat of juvenile finfish
RECREATION				
Boat slips exposed to *Bankia/Teredo*	No Benefit	No Benefit	No Benefit	No Benefit
Swimming	No Benefit	Slight reduction in density of nettles	Slight reduction in density of nettles	Slight reduction in density of nettles
Sport Fishing	No Benefit	Potential increase in preferred species due to moderate increase in habitat of juvenile finfish	Potential increase in preferred species due to slight increase in spawning area and moderate increase in habitat of juvenile finfish	Potential increase in preferred species due to moderate increase i habitat of juvenile finfish
Hunting (Waterfowl)	No Benefit	Potential increase in duck populations due to moderate increase in food for ducks (SAV)	Potential increase in duck populations due to moderate increase in food for ducks (SAV)	Potential increase in duck populations due t significant increase f food for canvasback (*Macoma*) and moderate increase in food for other ducks (SAV)
WATERS USERS	No Benefit	No Benefit	No Benefit	No Benefit
OTHER TRIBUTARIES	No Benefit	Will generally reduce salinit' s in the main bay near the mouth of the Rappahannock River during the summer	Will generally reduce salinities in the main bay near the mouth of the Rappahannock River during the spring and summer	Will generally reduce salinities in the main bay near the mouth of the Rappahanock River during the summer and fall

	No Action (Future Drought)	BENEFICIAL	DETRIMENTAL
OTHER SPECIES	No Benefit	Spring: Leptocheirus plumulosus Mesohaline phytoplankton Acartia clausi Summer: Prorocentrum minimum Chrysora quinquecirrha-polyp Heteromastus filiformis Rangia cuneata Fall: None	Spring: Polyhaline Phytoplankton Podon polyphemoides Ampelisca abdita Zostera marina Summer: Polyhaline Phytoplankton Ruppia maritima Mnemiopsis leidyi Chrysaora quinquecirrha - medusa Acartia tonsa Streblospio benedicti Urosalpinx cinerea Menidia menidia Mercenaria mercenaria Brevoortia tyrannus - Adult Micropogonias undulatus - Adult Leiostomus xanthurus - Adult Zostera marina Fall: Mulinia lateralis

It is clear that supplementing the freshwater inflows to Chesapeake Bay through reservoir storage would produce substantial benefits in the estuary. But, it should be emphasized that, like the other most promising alternatives, the reservoirs addressed in the study are not being recommended for construction; rather, they are measures that need to be further analyzed before any recommendation can be made. In particular, the upstream socio-economic and environmental impacts must be identified in detail to determine if the total benefits of reservoir storage outweigh the total costs. An important ingredient in these analyses are the local, regional, and National perspectives.

Another point that should be emphasized is the meaning of the word "reasonable" as it relates to quantities of storage. This determination was based solely on technical considerations and experience in previous studies. For the most part, it is a function of the amount of water that can be stored without materially affecting the natural variability of flows in the main stem of the rivers. The work associated with this study appears to indicate that the storage of a quantity of water equivalent to the amount of consumptive losses that will accumulate in two seasons during a severe drought in the year 2020 is the outer limit of technically feasible "reasonable" storage. Certainly, more detailed studies are needed to ascertain if this level of storage can be economically, socially and environmentally justified, or if some lesser level of storage is more appropriate.

CONSERVATION

The plan formulation exercise has identified the Susquehanna and Potomac Basins as those in which conservation has the potential for meaningful contributions to Bay resources. Benefits associated with conservation plans in these two basins are shown in Tables B-V-6 and 7. Since conservation plans are permanent measures which would provide flow supplmentation under all flow conditions, benefits would occur under both drought conditions and over the long-term average. For this reason, habitat changes for the major resources and benefits to other Bay resources are displayed for both long-term average and drought.

Generally, the habitat improvements related to conservation during a drought are significantly higher than improvements on the long-term average. Obviously, this is because the amount of water added through implementation of conservation measures is a much more significant portion of drought inflows than it is of long-term average ones.

On the Main Bay, the drought habitat for all major resources increases, especially in summer for soft clam, the tidal freshwater and oligohaline zone and oysters. Thus, as was found for reservoir storage, the most significant benefits are associated with flow supplementation plans during summer.

On the Potomac, principal drought habitat increases in the summer are shown for the tidal freshwater zone and soft clam. Tidal freshwater is also substantially expanded in both fall and winter, and Macoma is significantly expanded in fall.

Long-term average conservation benefits are small in both the Main Bay and the Potomac River. The most noticeable improvements in the Main Bay are for the soft clam and oyster in summer and Macoma in fall. Major beneficiaries in the Potomac are the summer tidal freshwater zone and soft clams.

Benefits to other resources, such as the commercial fishery and recreation, for both drought and average, are also described in Tables B-V-6 and 7. It should be noted that conservation also may induce peripheral benefits to water supply systems through reductions in water demand. Reduced per capita demands would result in reduced costs for water supply source development, and water treatment and distribution system construction. These system savings, on the long-term, could somewhat, if not entirely, offset the costs of implementing conservation.

GROWTH RESTRICTIONS

Specific plans for growth restrictions have not been developed. A general discussion of the benefits associated with this type of action is warranted, however, due to their potential for wide-ranging effects on water use in the Bay drainage basin.

The general beneficial effects of growth restrictions are similar to conservation. However, the magnitude of reduction in consumptive losses is potentially much greater. The quantities of water that could be saved would depend on the types and amounts of water uses projected to occur in an area and the degree and type of growth restrictions imposed. For example, imposition of restrictions on growth for industries such as power could be very significant in the Susquehanna River Basin. Projections used in this study indicate that consumptive losses due to power generation in the Susquehanna will increase over 500 mgd by the year 2020. This represents about one-half of the storage estimated to be required to attain summer Base Drought levels of inflow.

Benefits arising from controls on growth would occur in the Bay in the same manner as described in Table B-V-6 and 7 for conservation. Inflows would be permanently increased year round (except for irrigation) and all species adversely affected by increased consumptive losses would be benefited. The relative degree of improvement would be a function of the reduction in consumptive losses.

A number of important considerations would accompany this type of plan. Care would be required in implementation since a restriction on growth in one area may merely result in a transferal to another area. Since this type of measure would be highly controversial, political actions at many levels would be required before implementation. Individual study of the social and economic implications of such a plan would also be required.

OYSTER BED RESTORATION

Oyster bed restoration is a management type of plan that could improve Bay resources without acting to control salinities in Chesapeake Bay. The programs would involve both the seeding and shelling of existing oyster beds. These types of activities are elements of programs for oyster protection and enhancement in both Maryland and Virginia. The programs have proven cost effective, on a limited scale, in improving oyster harvests in these states. If managed on a long-term continuing basis, oyster bed restoration may contribute to mitigating a large portion of the damage caused by consumptive losses. This could help to alleviate the periodic adverse effects of drought, as well as improve harvest on the long-term average.

Benefits associated with oyster bed restoration would depend on the costs of bed development compared to the value of the increased harvest. Indications are that intensive management of bars could substantially increase the average yields.

TABLE B-V-6

BENEFITS OF SUSQUEHANNA RIVER CONSERVATION PLAN

MAJOR RESOURCES		No Action (Future Drought) Habitat (KM^2)	No Action (Future Drought) Impact Ratio	Conservation (During Drought) Change in Habitat (KM^2)	Conservation (During Drought) Change in Habitat (%)	Conservation (During Drought) Impact Ratio	No Action (Future Average) Habitat (KM^2)	No Action (Future Average) Impact Ratio	Conservaton (Long Term Average) Change in Habitat (KM^2)	Conservaton (Long Term Average) Change in Habitat (%)	Conservaton (Long Term Average) Impact Ratio
Oysters	(Summer)	450	.24	60	13	.27	1,110	.59	100	9	.64
Oligohaline Zone Species	(Spring)	760	.74	10	1	.75	1,060	1.03	-5	0	1.02
	(Summer)	120	.19	15	13	.21	610	.95	5	1	.96
	(Fall)	100	.45	25	25	.56	200	.90	5	3	.92
	(Winter)	200	.31	0	0	.31	665	1.04	5	1	1.0[illegible]
Tidal Freshwater Zone Species	(Spring)	125	.57	5	4	.59	245	1.11	-5	-2	1.[illegible]9
	(Summer)	29	.18	11	38	.25	150	.94	2	1	.95
	(Fall)	15	.13	0	0	.13	90	.75	5	6	.79
	(Winter)	46	.25	5	11	.28	180	.97	0	0	.97
Submerged Aquatic Vegetation	(Spring)	645	.54	10	2	.54	760	.80	35	5	.83
	(Summer)	390	.57	5	1	.58	630	1.02	5	1	1.03
Soft Clam	(Summer)	1	0	14	1400	.03	265	.55	40	15	.64
Macoma	(Fall)	755	.34	60	8	.37	1,110	.60	125	11	.67

	No Action (Future Drought)	Conservation (During Drought)	No Action (Future Average)	Conservaton (Long Term Average)
COMMERCIAL FISHERY	No Benefits	Potential increase in harvest due to moderate increase in habitat for oysters and juvenile finfish, slight increase in spawning areas, and significant increase in habitat of soft clam	No Benefit	Potential increase in harvest due to slight increases in oyster habitat and habitat for juvenile finfish and moderate increase in habitat for soft clam
RECREATION				
Boat slips exposed to *Bankia/Teredo*	No Benefit	Slightly reduced	No Benefit	Slightly reduced
Swimming	No Benefit	Slight reduction in density of nettles	No Benefit	Slight reduction in density of nettles
Sport Fishing	No Benefit	Potential increase in preferred due to moderate increase in habitat for juvenile finfish and slight increase in spawning area	No Benefit	No discernable change
Hunting (Waterfowl)	No Benefit	Potential increase in duck populations due to slight increases in food for canvasback (*Macoma*) and other ducks (SAV)	No Benefit	Potential increase in duck populations due to slight increases in food for canvasback (*Macoma*) and other ducks (SAV)
WATER USERS	No Benefit	No discernible change	No Benefit	No discernible change
OTHER TRIBUTARIES	No Benefit	No discernible change	No Benefit	No discernible change
OTHER SPECIES	No Benefit	Will slightly benefit all species which are adversely affected by increases in salinity	No Benefit	Will slightly benefit all species which are adversely affected by increased in salinity

TABLE B-V-7

BENEFITS OF POTOMAC RIVER CONSERVATION PLAN

PROBLEM SPECIES		No Action (Future Drought) Habitat (KM^2)	Impact Ratio	Conservation (During Drought) Change in Habitat (KM^2)	Change in Habitat (%)	Impact Ratio	No Action (Future Average) Habitat (KM^2)	Impact Ratio	Conservation (Long Term Average) Change in Habitat (KM^2)	Change in Habitat (%)	Impact Ratio
Oysters	(Summer)	295	.44	15	5	.47	575	.87	15	3	.89
Oligohaline Zone Species	(Spring)	145	.28	-5	-3	.27	460	.87	10	2	.69
	(Summer)	150	.94	5	3	.97	220	1.38	10	5	1.44
	(Fall)	47	.23	0	0	.23	175	.86	5	3	.88
	(Winter)	43	.24	1	2	.24	205	1.14	-5	-2	1.11
Tidal Freshwater Zone Species	(Spring)	110	.42	5	5	.44	245	.94	2	1	.95
	(Summer)	15	.10	5	33	.13	95	.64	10	11	.70
	(Fall)	2	.03	3	150	.08	50	.82	2	[illegible]	.85
	(Winter)	2	.02	2	100	.03	155	1.17	-5	-3	1.13
Submerged Aquatic Vegetation	(Spring)	230	.51	10	4	.53	400	.88	10	3	.91
	(Summer)	150	.41	10	7	.44	360	.99	0	0	.99
Soft Clam	(Summer)	1	0	1	100	.01	80	.44	20	25	.55
Macoma	(Fall)	120	.20	40	33	.27	510	.87	10	2	.89

	No Action (Future Drought)	Conservation (During Drought)	No Action (Future Average)	Conservation (Long Term Average)
COMMERCIAL FISHERY	No Benefit	Potential increase in harvest due to slight increase in spawning area and habitat for oysters, soft clams and juvenile finfish	No Benefit	Potential increase in harv- due to slight increase in spawning area and habitat f oysters and juvenile finfis and significant increase i habitat for soft clam
RECREATION				
Boat slips exposed to Bankia Teredo	No Benefit	Slightly reduced	No Benefit	Slightly reduced
Swimming	No Benefits	Slight reduction in density of nettles	No Benefit	Slight reduction in density of nettles
Sport Fishing	No Benefits	Potential increase in preferred species due to slight increase in spawning areas and habitat of juvenile finfish	No Benefit	Potential increase in prefe red species due to slight increase in spawning areas habitat of juvenile finfish
Hunting (Waterfowl)	No Benefits	Potential increase in duck populations due to significant increase in food for canvasback (Macoma) and slight increase in food for other ducks (SAV)	No Benefit	Potential increase in duck populations due to slight increases in food for (Macoma) and other ducks

	No Action (Future Drought)	Conservation (During Drought)	No Action (Future Average)	Conservation (Long Term Average)
WATER USERS	No Benefit	No discernible change	No Benefit	No discernible change
OTHER TRIBUTARIES	No Benefit	No discernible change	No Benefit	No discernible change
OTHER SPECIES	No Benefit	Will slightly benefit all species which are adversely affected by increases in salinity	No Benefit	Will slightly benefit all species which are adversely affected by increases in salinity

FINFISH RESTOCKING

Finfish restocking is another of the Bay-wide management measures. Its objective is to increase the population of particular species. Of predominant concern in Chesapeake Bay are striped bass and shad. Populations of these species are presently severely depressed for reasons that are not entirely understood. The effects of reduced freshwater inflows could significantly impact the summer nursery areas for these species, thereby aggravating an already severe situation.

Finfish restocking involves the rearing of large numbers of young fish and introducing them to the estuary. Programs have been undertaken recently in attempts to reverse the severe population declines of shad and striped bass evidenced in recent years. Similar actions would potentially be effective in offsetting the effects of increased consumptive losses in Chesapeake Bay.

Benefits of finfish restocking are difficult to document since field data are inconclusive as to the success of these programs in supplementing fishery populations. An advantage of finfish restocking is that species of particular concern may be helped. This may be a short-term solution, however, for what may actually be a long-term, continuing problem. These plans also require high expenditures for physical plant, land and operations. Also, there is significantly less certainty of success than exists for oyster bed restoration. Despite a number of evident drawbacks, however, these plans are assumed to be generally beneficial.

CATCH RESTRICTIONS

Catch restrictions are the third Chesapeake Bay management option. Included are laws which dictate conditions under which finfish or shellfish can be caught. These are generally size, sex or catch size limitations. A difficulty in the evaluation of catch restrictions exists because their effectiveness in the estuary is unknown. The basic objective is to protect a sufficient population to allow natural regeneration of the target species. Programs in the Bay region for species such as striped bass and shad have had mixed results.

Principal benefits associated with catch limitations include the lack of need for physical structures and land. Thus, the costs of implementation will be lower relative to finfish restocking or oyster bed restoration. The program is primarily oriented to enhancement of the long-term average standing stocks through maintenance of a healthy base population. This would also help reduce the periodic effects of drought.

A basic disadvantage of catch restrictions is that policing actions would be required to assure that commercial and/or recreational fishermen are complying with the regulation. Also, difficulties may occur in implementing measures of this type due to segments of the population which depend on the Bay's fin and shellfish for their livelihood or recreation enjoyment.

PLANS OF OTHERS

Important additional considerations are the existing measures in Chesapeake Bay which relate to regulation of freshwater inflow. The two most prominent are the

environmental flowby on the Potomac River and the requirements for consumptive loss make-up on the Susquehanna.

Potomac Low Flow Allocation Agreements

The Low Flow Allocation Agreement, signed in 1978 and modified in 1982, provides for an equitable means of allocating Potomac River water among users in the Metropolitan Washington Area. Under provisions of the Agreement, no area will suffer disproportionate shortages during low flow periods. The Agreement further provides for a review every five years to determine the fairness and reasonableness of the allocation formula. Should further action be needed in the future to balance supplies and demands, this Agreement furnishes the logical means by which needs can be identified and appropriate actions undertaken. The LFAA also stipulates that a certain amount of flow be allowed to enter the Potomac Estuary as environmental flowby. The LFAA signatories have adopted a 100 mgd value for minimum flowby to the Estuary, based on the recommendations in Maryland's Flowby Study.

Susquehanna Minimum Flow Criteria

The Susquehanna River Basin Compact created the Susquehanna River Basin Commission through enactment of concurrent legislation by the States of New York and Maryland, the Commonwealth of Pennsylvania and the United States of America. Article II of the Compact grants authority for the Commission to "regulate and control withdrawals and diversions from surface waters and ground waters of the basin . . ." In September 1976, the Commission established a regulation specifying a low flow criterion, in accordance with the previously adopted Comprehensive Plan, mandating that "Compensation shall be required for consumptive uses (of water) during periods of low flow." In lieu of direct monetary compensation, the regulation requires consumptive users to provide water in the total amount consumed during periods of low flow.

The minimum low flow criteria selected is termed the 7 day, 10 year low flow (stream flow rate during seven consecutive day, with a 10 percent chance of occurring in any year). For the Susquehanna at Marietta, Pennsylvania, this minimum flow is 2,480 cfs.

Of interest is the relationship of this criteria to the projections of consumptive losses used in this study and the requirements for flow supplementation plans. Historical records for the period of October 1962 through September 1966 were searched to determine if flows at Marietta during this period were below the minimum flow established by the SRBC.

This period is important because the Low Freshwater Inflow Study is based partly on flows recorded during this period. The search revealed that there were 60 daily flows below the established SRBC minimum for the period. In fact, the minimum flow for the period was 1,450 cfs which occurred September 27, 1964. This is far below the established SRBC minimum flow. For this same September, there occurred 20 consecutive days of daily flows below the 2,480 cfs minimum allowable flow established by the SRBC. It is therefore apparent that, during a drought similar to the 1960's drought, it would be necessary to provide for reservoir storage and/or drought emergency measures to insure that flows never fall below the acceptable minimum level.

When the 60's drought flows are reduced by 2020 consumptive losses and alarmingly large number of daily flows are less than the present SRBC minimum flow level. Projecting the 60's drought to the year 2020 yields 267 daily flows below the present SRBC minimum. All these flows occur in the summer and fall seasons. There would be 100 consecutive days of flow below the established minimum. There would be two days of 0 cfs flow and 11 days with flows below 500 cfs.

According to SRBC's Water Management Plan, compensation for consumed water during flow periods below the established minimum may be provided from water stored in existing reservoirs, or, if that storage is not adequate, new reservoirs will be needed. Other compensation alternatives are conservation and/or drought emergency measures. In the SRBC jurisdiction, this could include the discontinuance of operation for consumptive users who are unable to compensate for their water use. These alternatives are consistent with the most promising alternatives identified in this study.

CHAPTER VI

RISK AND UNCERTAINTY — SENSITIVITY ANALYSIS

Many assumptions have been made in the course of this study's investigations of the effects of potential reductions in freshwater inflow on the socio-economic and environmental values of Chesapeake Bay. In general, this is not surprising given the uncertainties of economic, demographic, environmental and technological trends, and the complexities of the ecosystem.

In this chapter, a look is taken at how changes in principal assumptions could affect study findings. Also, a section is provided illustrating how often droughts could be expected that are of the same magnitude as the 1960's drought. This relates to the risk that is associated with the no action plan.

OBERS 1980 PROJECTIONS

Projections of population, economic activity and water use for the Chesapeake Bay drainage basin were derived from the Second National Water Assessment, U.S. Water Resources Council, 1978. The WRC's analysis was based on the OBERS Series E projection set published in 1974. The projections of consumptive losses from the National Assessment were used to create hydrographs for the year 2020 for the hydraulic model tests (see Appendix C).

Since that time, the 1980 census has been completed and demographic and economic base information has been updated by the U.S. Department of Commerce. Since the "OBER 1980" projections have implications in water use and consumption, a comparison of these most recent projections with the projections which formed the basis of the low flow analysis is warranted.

Ideally, the water use projections themselves could be compared. However, consistent information that would allow for ease of comparison are very limited. For example, OBERS 1980 projections do not exist for the Water Resource Regions used in the National Assessment. The only data strictly comparable are data for the various states. But these are not particularly representative of economic activity in the Bay drainage basin. Large portions of Pennsylvania and Virginia lie outside the Bay area.

For these reasons the six most prominent Economic Areas influencing the Bay have been aggregated for purposes of assessing major differences between Series E and OBERS 1980 projection sets. These areas, however, were redefined by BEA in 1977. These changes are detailed in Chapter II of Appendix A. Most noteable are the differences in the Harrisburg Economic Area, which lost six counties, Baltimore which lost four counties, and Washington, D.C., which gained 15 counties. Although these changes have affected the size and shape of the Economic Areas, the percentage changes in population are minor.

A plot of population for the aggregated group of six Economic Areas (the "Greater Bay area"), for both Series E and OBERS 1980 projection sets, is shown in Figure B-VI-1. The slope of the Series E projection is significantly steeper than that of the 1980 OBERS projection indicating that the gap between the two sets of projections is widening over

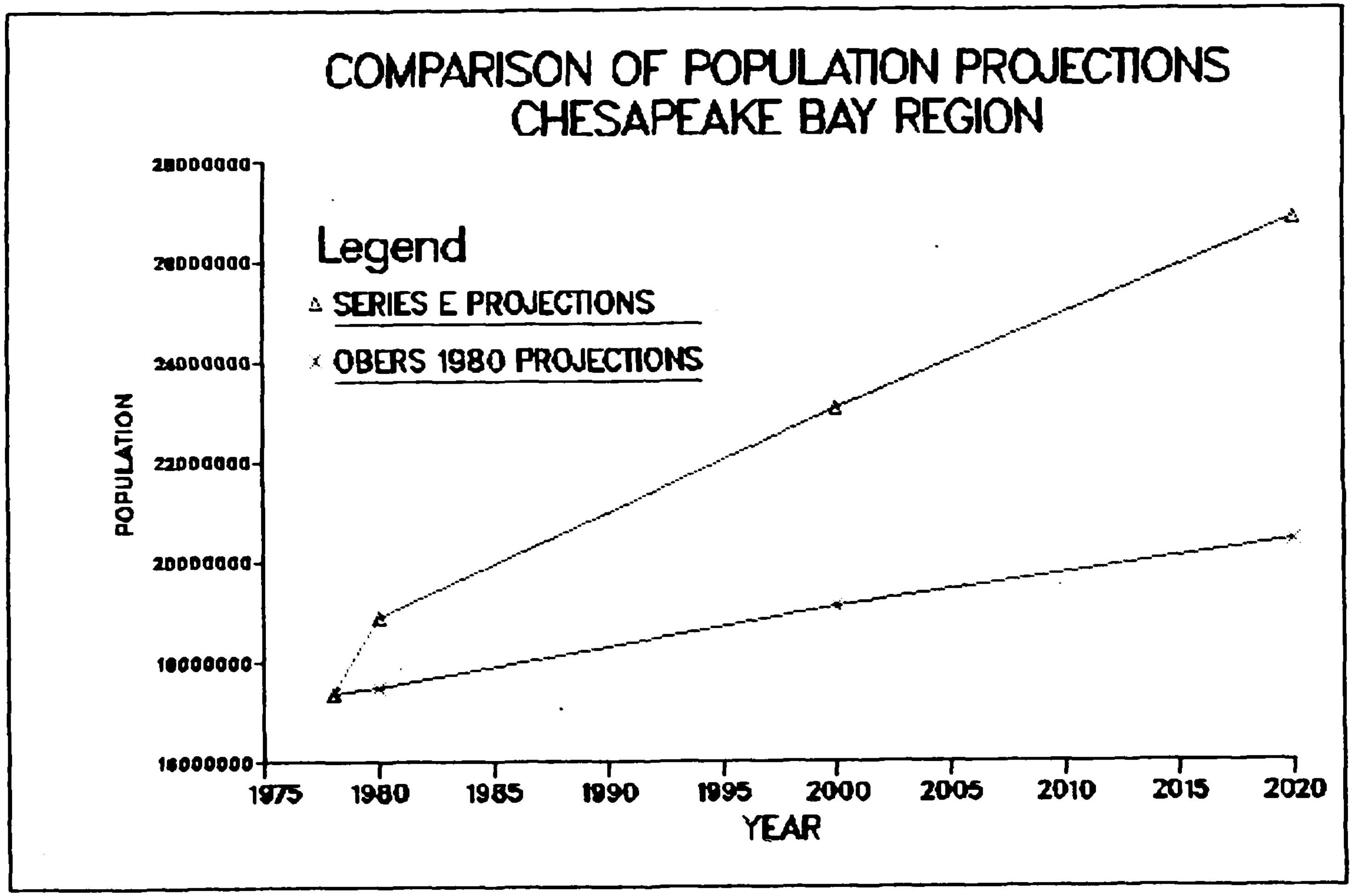

FIGURE B-VI-1: COMPARISON OF POPULATION PROJECTIONS
CHESAPEAKE BAY REGION

the range of the projections. Similarly, Figures B-VI-2 through 7 show that Series E projections are consistently higher than OBERS 1980 projections for all the BEA Economic Areas except Richmond and Norfolk. The OBERS 1980 projections presented in the figures are for the "no-change-in-share" assumption for each Economic Area relative to the employment projections for each state. This assumption was chosen in the absence of data favoring another scenario for the future.

A tabular comparison of the population changes for Series E and OBERS 1980 is presented in Table B-IV-1. Under OBERS 1980 projections, greatest absolute reduction in 2020 population occurs in the Washington, D.C., Economic Area, which declines 2.8 million people, or about 38 percent. The greatest increase in population difference is shown for the Norfolk Economic Area (19 percent, or 0.3 million people).

Overall, the population of the Greater Bay Region is predicted to be 6.4 million less under OBERS 1980 than under Series E. This is a 24 percent reduction. Since these 2020 population projections are related to the water use statistics used to identify impacts for the Low Freshwater Inflow Study, this magnitude of change may be significant in certain of the Bay's drainage basins.

Table B-VI-2 contains a comparison of Series E and OBERS 1980 employment projections. Due to changes in assumptions regarding future employment rates, the OBERS 1980 data reflect a higher percent employment in all areas than Series E. Thus, while population in the "Region" was shown to be 24 percent lower with OBERS 1980, employment is only 18 percent lower.

The significance of the differences in population projections is open to argument and certainly subject to interpretation. It is clear that estimates of consumptive loss and withdrawals of freshwater based on Series E projections are overstated assuming that OBERS 1980 projections more accurately depict the most probable future conditions. Other social and economic variables will also affect future water use in ways which have not been anticipated. Power generation consumptive losses, for example, have been lowered in recent estimates.

Without an analysis on a sector by sector basis, it is difficult to reconstruct new water use projections for a strict comparison with the originals. Short of this, it is probably sufficient to note that the lower growth rates estimated at present may simply forestall realization of certain critical levels of key variables, such as consumptive losses, until a later date. The true implications of such a delay for the study's conclusions or recommendations can only be guessed at because a 20 year delay in attaining a given population level can be accompanied by significant changes in other relevant variables such as technology, consumer behavior, unanticipated shifts in agricultural irrigation policy or demands for water from out-of-basin.

BIOLOGICAL UNCERTAINTIES

In this study, the principal tool for identification of organism impacts has been the quantification of potential habitat as defined by salinity, depth, substrate and direct species interactions. Determination of these direct effects were relatively straightforward. Uncertainties arise, however, in attempting to translate these variables into productivity and organism abundance. Many variables which originate both

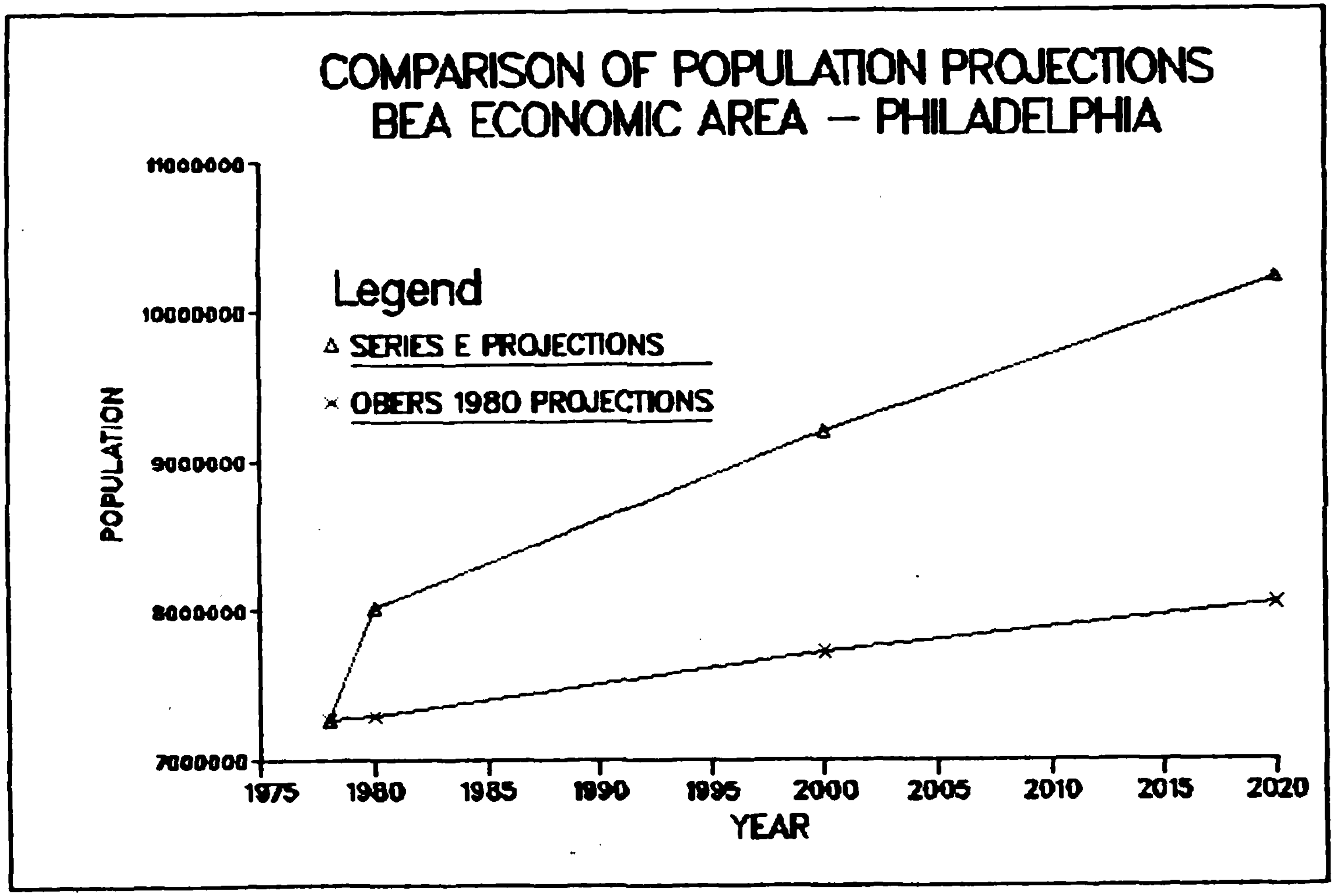

FIGURE B-VI-2: COMPARISON OF POPULATION PROJECTIONS
BEA ECONOMIC AREA - PHILADELPHIA

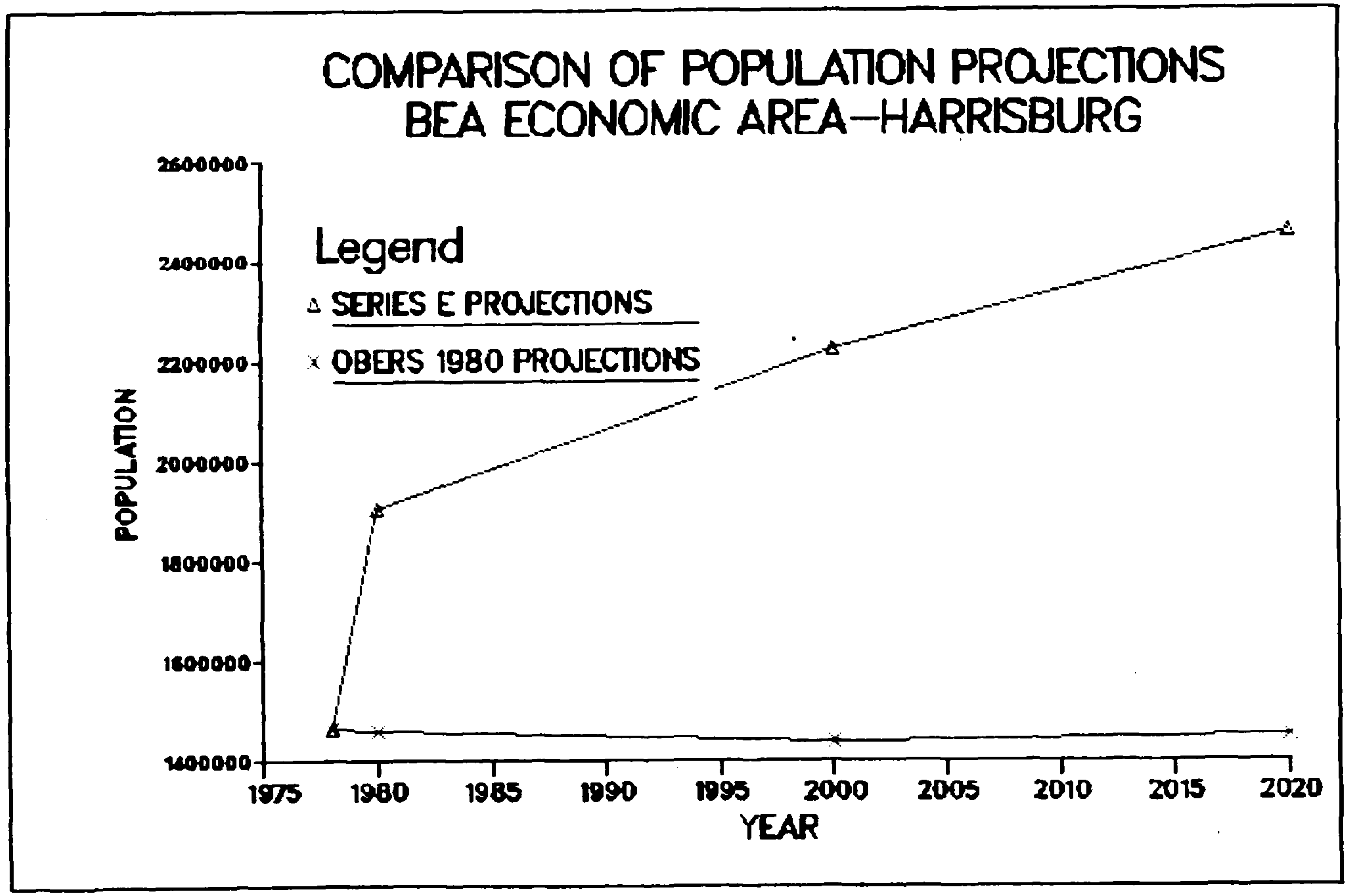

FIGURE B-VI-3: COMPARISON OF POPULATION PROJECTIONS
BEA ECONOMIC AREA - HARRISBURG

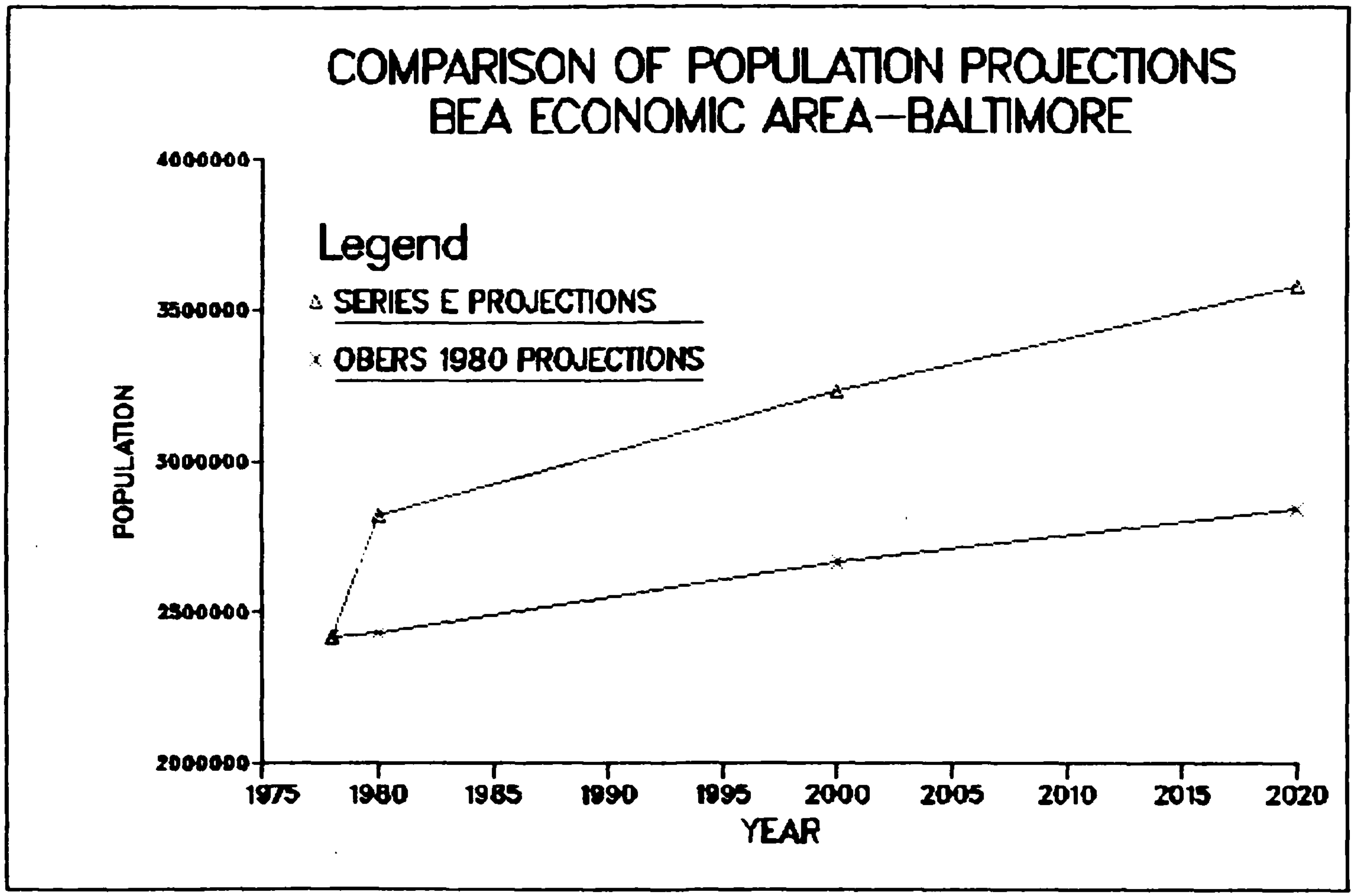

FIGURE B-VI-4: COMPARISON OF POPULATION PROJECTIONS
BEA ECONOMIC AREA - BALTIMORE

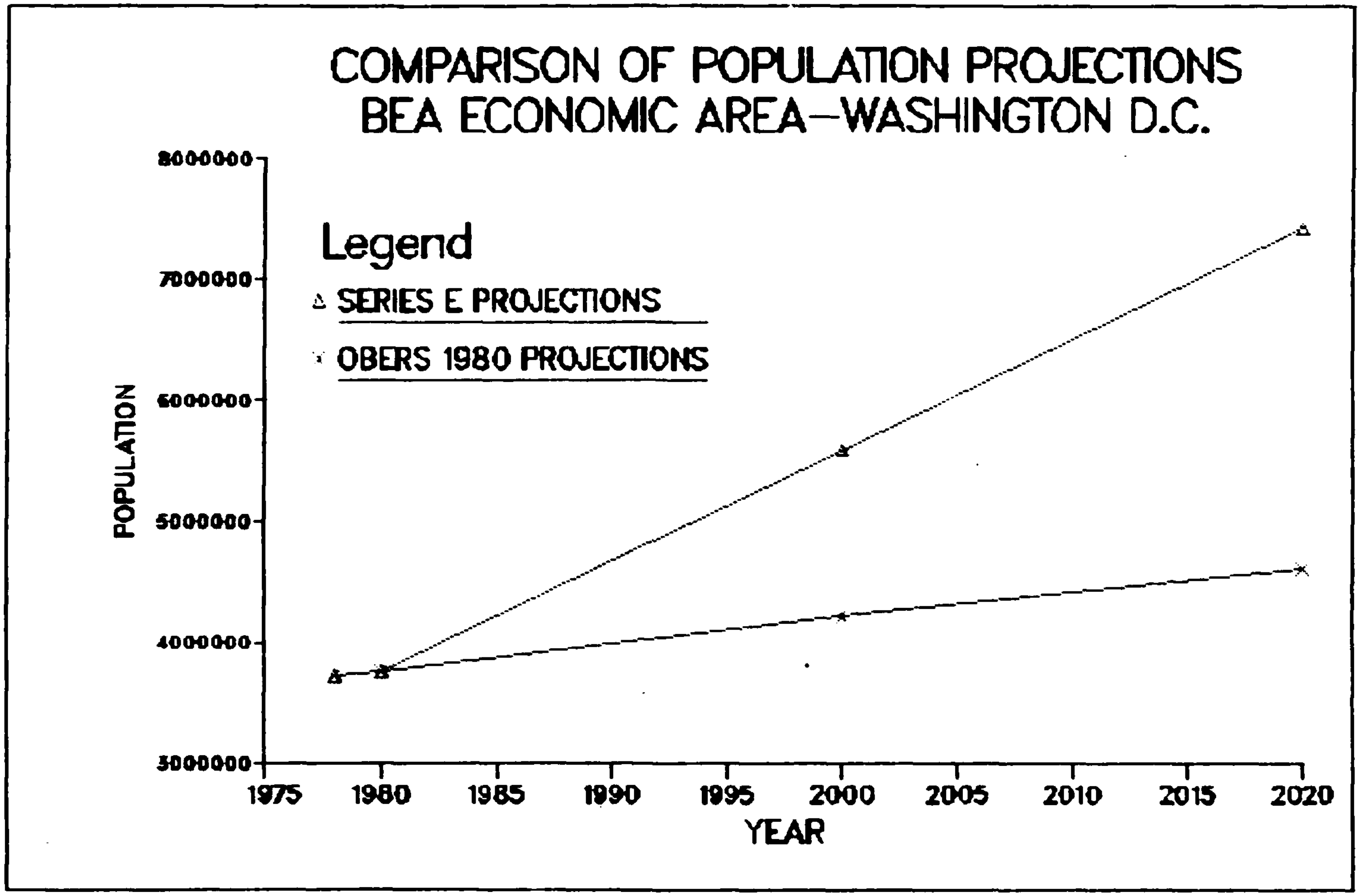

FIGURE B-VI-5: COMPARISON OF POPULATION PROJECTIONS
BEA ECONOMIC DATA - WASHINGTON D.C.

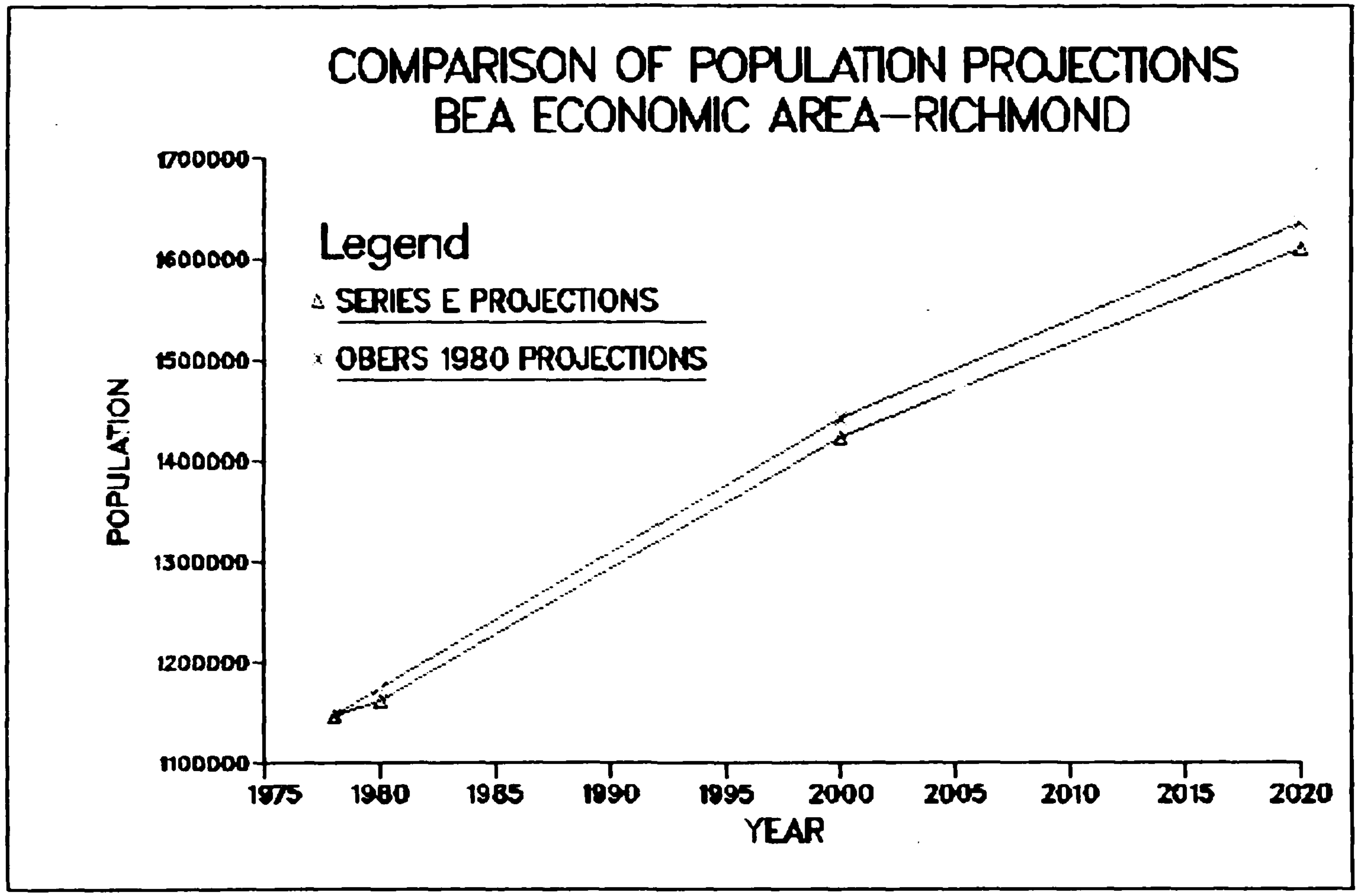

FIGURE B-VI-6: COMPARISON OF POPULATION PROJECTIONS
BEA ECONOMIC DATA - RICHMOND

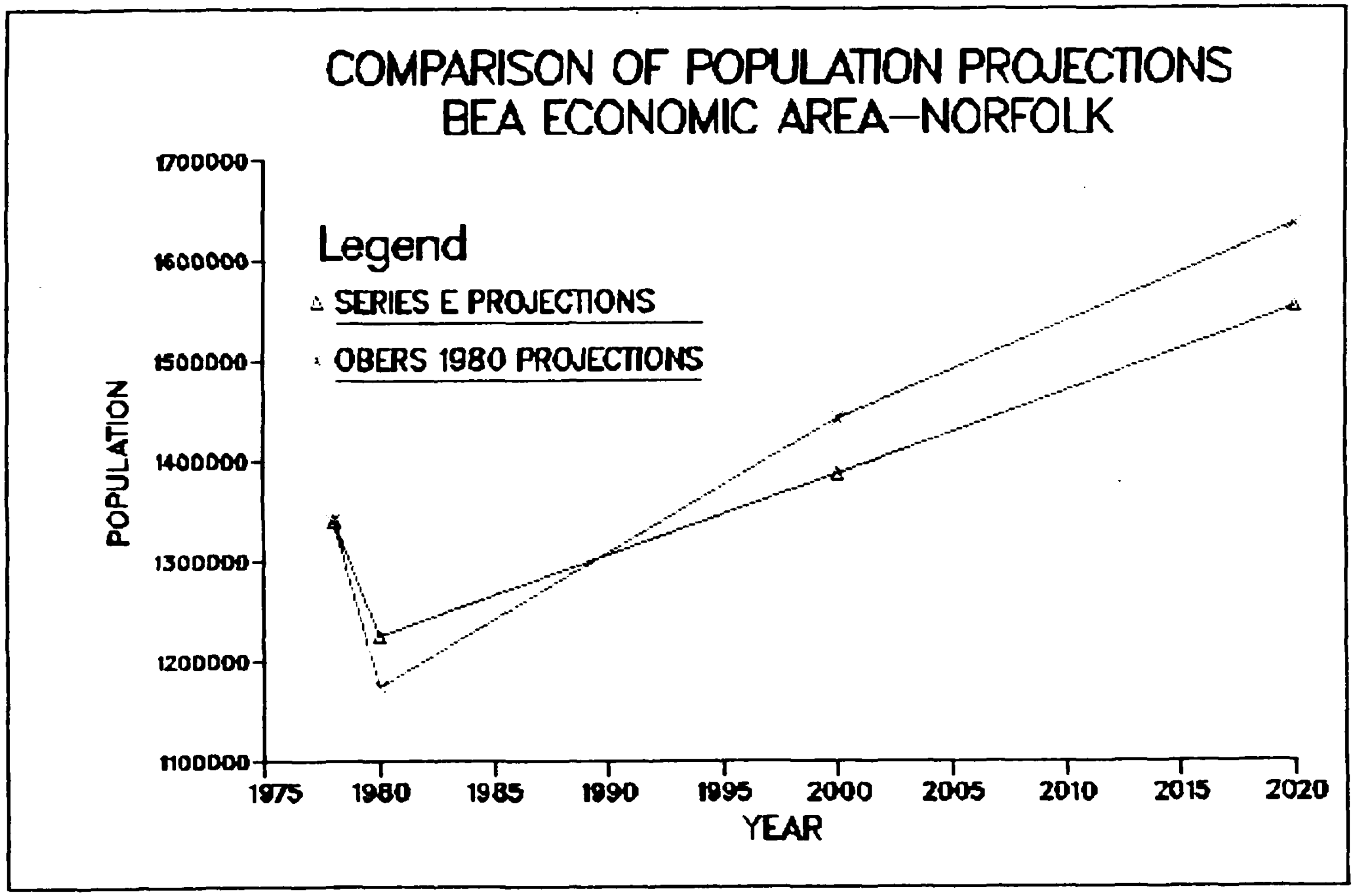

FIGURE B-VI-7: COMPARISON OF POPULATION PROJECTIONS
BEA ECONOMIC DATA - NORFOLK

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TABLE B-VI-1
POPULATION COMPARISON: SERIES E AND OBERS 80

5 No.	Economic Area Name	2020 Population (millions) Series E	OBERS 1980[1]	Change Number (Millions)	Percent
18	Philadelphia	10.22	8.05	-2.17	-21.2
17	Harrisburg	2.46	1.45	-1.01	-41.1
19	Baltimore	3.58	2.85	-0.73	-19.0
20	Washington	7.42	4.61	-2.81	-37.9
22	Richmond	1.61	1.63	+0.02	+ 1.2
23	Norfolk	1.55	1.84	+0.29	+18.7
"Greater Bay Region"		26.83	20.43	-6.40	-23.9

(1) Interpolated from published 2000 and 2030 information.

TABLE B-VI-2
EMPLOYMENT COMPARISONS: SERIES E AND OBERS 80

No.	Economic Area Name	2020 Employment (millions) Series E	OBERS 80	Change Number (Millions)	Percent
18	Philadephia	4.58	3.83	-0.75	-16.4
17	Harrisburg	1.12	0.76	-0.36	-32.1
19	Baltimore	1.61	1.30	-0.31	-19.3
20	Washington	3.48	2.44	-1.04	-29.9
22	Richmond	0.72	0.85	+0.13	+18.1
23	Norfolk	0.70	0.88	+0.18	+25.7
"Greater Bay Region"		12.21	10.06	-2.15	-17.6

externally and internally to the estuarine system are not sufficiently understood to allow prediction, with a high degree of confidence, the end result of a perturbation such as a change in freshwater inflow. Indeed, there are some very substantial problems in attempting to predict the seasonal patterns of such basic features of an estuarine system as primary production. A generalized diagram of the physical, chemical and biological interactions affecting ecosystem productivity is shown in Figure B-VI-8. Due to the many unknowns involved in deciphering these many interactions, a Biota Evaluation Panel was convened. It incorporated, through expert judgement, as many ecosystem variables as possible in predicting the meaning of the identified salinity and habitat changes. Subsequent determinations of the social and economic implications of the Panel's findings were done by the Corps of Engineers.

The following sections present an overview of the confidence that can be placed in the biological changes predicted by the Panel and the Corps' staff. The certainty, or confidence, with which results generated in this study can be viewed varies by species.

The most confidence can be placed in the estimates made for oysters. This is due to the well documented (and apparently quite direct) relationship between oyster health and the range of disease organisms and predators. There is relative confidence in the continued productivity of oysters in areas that maintain salinities less than the required 15 ppt. Pest and disease organisms are active at salinities greater than 15 ppt.

Similar confidence is probably warranted for predictions for Macoma and soft clam. Similar to oysters, these animals are benthic forms and are non-migratory. For these organisms, and other benthics, in general, the effect of variation in one key habitat determining variable such as salinity is relatively more predictable in terms of organisms survival.

The relationship of the health and productivity of submerged aquatic vegetation to the habitat variables used in this study are not as distinct. Currently, SAV are severely reduced in their distribution and abundance in Chesapeake Bay. The reasons for this are unclear but, at present, prime suspects are the murky waters caused by turbidity and nutrient enrichment. Similarly unclear is the role of changing salinity regimes in the distributional dynamics of SAV. The confidence in the predictions for SAV presented in this report are thus somewhat less than for oysters, soft clam and Macoma.

Uncertainties regarding finfish estimates are probably the greatest of all the biological predictions. Direct cause and effect relationships for reduced freshwater inflow and drought on fish of the Chesapeake estuary are not well established. At the current state of knowledge, the scientific community cannot directly equate change in potential habitat with change in stock levels. It is felt, however, that a change in habitat must result in change for the dependent biota.

An obstacle in estimating impacts on fisheries stocks is that a change in populations due to decreased freshwater inflow may not be discernible from "normal" population variation. Bay biologists are currently unable to define what normal or acceptable limits are for the various fish stocks. Thus, estimates of varying commercial fisheries catch should be considered most uncertain of all estimates presented in this report.

CHEMICAL AND PHYSICAL INTERACTIONS WHICH AFFECT ECOSYSTEM PRODUCTIVITY

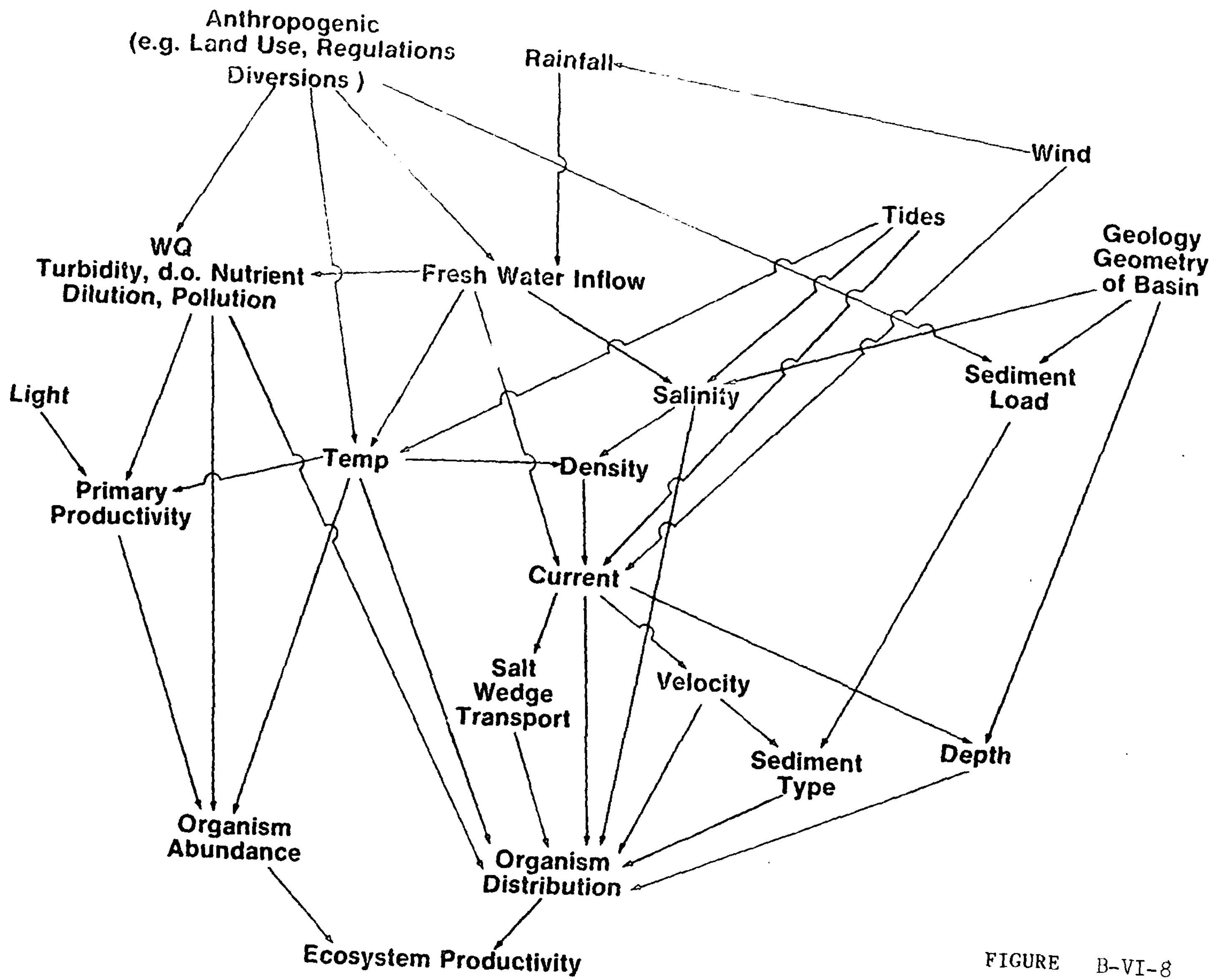

FIGURE B-VI-8

RISK OF DROUGHT OCCURENCE

It was assumed for the Low Freshwater Inflow Test that a drought would occur in the year 2020 time frame which would be similar in magnitude to the 1960's drought. To alleviate the effects of a drought in the year 2020, a series of alternative plans have been devised. However, it was recognized that if the 1960's drought was a rare event, there would be minimal risk involved in adopting a "No Action" plan. Conversely, if the 60's drought was a frequent event and a No Action plan was adopted, the risk involved could be much greater and could result in grave implications for the Bay system. Therefore, it is the purpose of this section to investigate whether the 1960's drought was indeed a rare or a frequent event.

The analysis began with the selection of the five major rivers within the Bay system, the Susquehanna, Potomac, James, York and Rappahannock Rivers. The flow records for these rivers are relatively short with the Susquehanna having the longest and the York River having the shortest period of record, 82 and 31 years respectively. The 60's drought period was then extracted from the records and seasonal drought averages were computed for one, two, three and four year durations. For example, the one year summer drought average would be the 1965 summer seasonal average flow, the two year summer drought average would be the average of 1964 and 1965 summer flows, and so on.

Seasonal flow averages for the period of record were then computed and compared to the seasonal 60's drought averages. All discrete flow periods which were equal to or less than the seasonal 60's drought averages were acumulated. The recurrence intervals are presented on Table B-VI-3.

From Table B-VI-3 it can be seen that, for the Susquehanna, only one summer period was drier than the summer of 1965. This implies a reccurrence of once every 41 years. Interestingly, there are no two or more consecutive summers drier than the 60's drought period for the Susquehanna River Basin.

For the fall season, nineteen periods in the Susquehanna were of a lesser magnitude than the fall of 1965. This is a reccurrence of once every 3.7 years. However, only two fall periods of two years duration were less than the 1965 fall average. This is a recurrence of once every 27 years. For the winter and spring seasons, drier periods are more frequent and of extended duration. Included are two spring periods of four year duration that have averages less than the 1963-66 spring averages.

At the southern extreme of the Chesapeake Bay, there were five summer and fall flow periods on the James River with flow averages less than the corresponding summer and fall 1965 flow averages. Drier winter and spring periods of extended duration have occurred on the James. Of particular note are four winter flow periods of four year duration with a recurrence of 14.8 years.

Overall it appears that the 1960's drought is the worst case drought scenario, especially in the critical summer and fall periods. It is also apparent that, in the lower Bay, there is a greater chance of summer average flow periods being less than the 1960's summer drought averages than in the upper Bay. Also, there is a greater chance of fall average flows lower than the 1960's fall drought averages occurring in the upper Chesapeake Bay.

TABLE B-VI-3
DROUGHT RISK ANALYSIS

River	Season	Flow Durations 1 Year	2 Year	3 Year	4 Year
Susquehanna (82 years of record)	Summer	1 (41)	0	0	0
	Fall	19 (3.7)	2 (27.3)	0	0
	Winter	26 (3.0)	8 (9.1)	4 (16.4)	1 (41)
	Spring	17 (4.6)	2 (27.3)	6 (12.0)	2 (27.3)
	Year	2 (27.3)	0	0	0
Potomac (77 years of record)	Summer	2 (25.7)	0	0	0
	Fall	1 (38.5)	1 (38.5)	0	0
	Winter	6 (11.0)	11 (6.4)	5 (12.8)	1 (38.5)
	Spring	16 (4.5)	14 (5.1)	9 (7.7)	5 (12.8)
	Year	2 (25.7)	1 (38.5)	1 (38.5)	0
James (74 years of record)	Summer	5 (12.3)	0	0	0
	Fall	5 (12.3)	1 (37)	0	0
	Winter	8 (8.2)	9 (7.4)	6 (10.6)	4 (14.8)
	Spring	7 (9.3)	7 (9.3)	3 (18.5)	2 (24.7)
	Year	1 (37)	1 (37)	0	0
York (31 years of record)	Summer	7 (8.9)	1 (15.5)	1 (15.5)	1 (15.5)
	Fall	1 (15.5)	2 (10.3)	0	0
	Winter	1 (15.5)	1 (15.5)	1 (15.5)	1 (15.5)
	Spring	1 (15.5)	2 (10.3)	1 (15.5)	1 (15.5)
	Year	1 (15.5)	2 (10.3)	1 (15.5)	0
Rappahannock (65 years of record)	Summer	4 (13.0)	0	1 (32.5)	0
	Fall	4 (13.0)	2 (21.7)	0	0
	Winter	6 (9.3)	7 (8.1)	3 (16.3)	3 (16.3)
	Spring	13 (4.6)	7 (8.1)	4 (13.0)	3 (16.3)
	Year	2 (21.7)	2 (21.7)	2 (21.7)	0

(   ) Recurrence interval in years.

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ATTACHMENT A

RESERVOIR STORAGE VOLUMES AND COSTS

This attachment is a supplement to the reservoir storage analysis presented in Chapter II. Based on an inventory of existing reservoir sites with a potential for reallocating storage for low flow purposes, and identification of potential new sites, total feasible storage volumes were computed. This was done for river basins found to be feasible for reservoir development. These are the Susquehanna, Potomac, James and Rappahannock Rivers.For the Susquehanna River, only the Keating, Towanda, East Guildford and Davenport Center projects were included in Table B-II-I. Likewise, for the James River, Genito, Hipes, and Upper Cartersville were included in Table B-II-I. These projects were identified as being reasonable and implementable. Tables 1 and 2 depict the pertinent data for existing and potential projects, respectively, in the Susquehanna River. Tables 3 and 4 present the results of assuming 20 percent of the non-committed conservation storage is available for low flow augmentation, and that 10 percent of that would be lost in instream flow. Tables 5 and 6 show the maximum storage available. Similar information is presented for the Potomac, James and Rappahannock Rivers in Tables 7 through 12.

Potential storage costs were also developed. They were not used in the evaluations however, and are presented for general information only.

Three sources of cost data were used to develop an average unit cost for construction of reservoirs. Data sources include construction costs of several recent Federal projects, estimated costs of a number of potential projects, and recent costs developed in connection with two detailed reallocation studies.

The recently constructed projects used in the analysis were the Corps' Raystown, Tioga-Hammond and Cowanesque Lake Projects. Actual construction costs were updated from the midpoint of construction to April 1983 price levels using the Engineering New-Record (ENR) Construction Cost Index. The storages of the projects considered ranged between 89,000 and 762,000 acre-feet. The unit costs developed for these projects are displayed in Table 13. The Susquehanna River Basin Flood Control Review Study dated August 1980 served as the basis for developing unit costs for eight potential projects. As shown on Table 14 the projects considered ranged in size from 30,000 to nearly 1.5 million acre-feet. Lastly, unit costs were developed for two projects (Cowanesque and Bloomington) that were the subject of recent detailed reallocation studies. Table 15 presents the unit costs as developed for these two projects.

In reviewing the results of the unit cost analyses it is noted that the unit costs range from a low of $274/acre-feet to a high value of $2,837/acre-feet. The projects considered ranged in size from 18,000 (reallocation) to 1,469,000 acre-feet. As would be expected, the unit costs for the larger projects are less than for the smaller projects.

TABLE 1(ATTACHMENT A)

SUSQUEHANNA RIVER BASIN
PERTINENT DATA FOR EXISTING RESERVOIRS

CAT	NAME OF PROJECT	LOCATION OF PROJECT	PROJECT PURPOSES	DRAIN AREA (SQ MI)	DISTANCE ABOVE MOUTH (MI)	STORAGE AT SPILLWAY (AC-FT)	FLOOD CONTROL STORAGE (AC-FT)	CONSERVE STORAGE (AC-FT)	LFA STORAGE (AC-FT)	INACTIVE STORAGE (AC-FT)
FED	INDIAN ROCK	YORK PA	F	94	50	28,000	28,000	0	0	0
	RAYSTOWN	HUNTINGDON PA	F/R/Q	960	180	762,000	248,000	514000	0	0
	FOSTER SAYERS	BLANCHARD PA	F/R/Q	339	205	99,000	70,180	28800	0	20
	AYLESWORTH	LACKAWANA CITY PA	F	6	220	1,764	1,700	0	0	64
	STILLWATER	FOREST CITY PA	F	37	235	12,000	11,571	343	0	86
	ALVIN R BUSH	RENOVA PA	F/R	226	235	75,000	73,254	1745	0	1
	CURWENSVILLE	CURWENSVILLE PA	F/R/Q	365	305	124,200	114,490	9540	0	170
	COWANESQUE	LAWRENCEVILLE PA	F/R/W	298	340	89,000	56,350	32600	25600	50
	TIOGA-HAMMOND	TIOGA PA	F/R	402	350	125,000	106,650	18350	0	0
	WHITNEY POINT	WHITNEY POINT NY	F/R	255	353	86,500	74,000	12500	0	0
	ALMOND	HORNELL NY	F/R	56	370	14,640	13,725	915	0	0
	ARKPORT	ARKPORT NY	F	31	375	7,950	7,950	0	0	0
	EAST SIDNEY	SIDNEY NY	F/R	102	405	33,550	30,000	3500	0	50
FED	13					1,458,604	835,870	622,293	25,600	441
NON-FED	MARBURG	SPRING GROVE PA	R/W	24	55	53,100	0	53100	4600	0
	DEHART RES	DAUPHIN PA	W	22	85	23,600	0	23600	23600	0
	SHAWNEE DAM	NAPIER TWSP PA	F/R	38	185	16,750	13,000	3750	0	0
	LITTLE PINE CREEK	WATERVILLE PA	F/R	165	185	24,800	23,700	1100	0	0
	PIKES CREEK	CEASETOWN PA	W	12	192	10,556	0	10556	10556	0
	HARVEYS LAKE	KUNKLE PA	R	7	200	23,900	0	23900	0	0
	GLENDALE	COALPORT PA	F/R	42	215	41,200	15,900	25300	0	0
	LACKAWANNA	FACTORYVILLE PA	R	45	225	14,200	0	14200	0	0
	CLARENCE F WALKER	TROXELVILLE PA	F/R	18	225	11,600	8,847	2753	0	0
	GEORGE B STEVENSON	SINNMAHONING PA	F	243	255	75,800	73,800	2000	0	0
	STILL CREEK	STILL CREEK PA	W	7	270	11,587	0	11587	11587	0
	COLLIERSVILLE DAM	OTSEGO CO NY	R	351	420	10,300	0	10300	0	0
	OTSEGO	COOPERSTOWN NY	R/W	75	430	39,800	0	39800	12360	0
NON-FED	13					357,193	135,247	221,946	62,703	0
	26					1,815,797	971,117	844,239	88,303	441

TABLE 2(ATTACHMENT A)

SUSQUEHANNA RIVER BASIN
PERTINENT DATA FOR POTENTIAL PROJECTS

CAT	NAME OF PROJECT	LOCATION OF PROJECT	PROJECT PURPOSES	DRAIN AREA (SQ MI)	DISTANCE ABOVE MOUTH (MI)	STORAGE AT SPILLWAY (AC-FT)	FLOOD CONTROL STORAGE (AC-FT)	CONSERVE STORAGE (AC-FT)	LFA STORAGE (AC-FT)	INACTIVE STORAGE (AC-FT)
FED	SHADY GROVE	MOGUL PA	R/W/Q	86	70	60,000	0	59300	0	700
	KEATING	KEATING PA	F/R/W/H	1,586	235	1,469,000	254,000	1200000	600000	15000
	SINNEMAHONING	KEATING PA	F/R/W	1,052	237	409,000	253,000	146000	73000	10000
	TOWANDA	FRANKLINDALE PA	F/R/Q	115	270	125,000	28,000	97000	48500	0
	FABIUS	FABIUS NY	F/R/W/Q	36	340	31,000	10,000	20650	10425	150
	MUD CREEK	SAVONA NY	F/R/W/Q	75	340	38,000	10,000	27500	13750	500
	GREAT BEND	HALLSTEAD PA	F/R/W/H	2,018	345	1,300,000	310,000	990000	495000	0
	GENEGANTSLET	GREENE NY	F	95	350	30,195	30,195	0	0	0
	FIVEMILE CREEK	WHEELER NY	F/R/W/Q	66	354	51,000	18,000	32600	16300	400
	SOUTH PLYMOUTH	NORWICH NY	F/R/W	57	380	38,000	17,000	20850	10425	150
	EAST GUILFORD	SIDNEY NY	F/R	523	395	175,000	70,000	103500	51750	1500
	COPES CORNER	COPES CORNER NY	F	118	400	37,900	37,900	0	0	0
	WEST ONEONTA	WEST ONEONTA NY	F	108	415	34,500	34,500	0	0	0
	DAVENPORT CENTER	DAVENPORT NY	F/W/Q	164	425	127,000	44,800	82000	41000	200
FED	14					3,925,595	1,117,395	2779,600	1360,150	28,600
NON-FED	10 CONEWAGO	STRINESTOWN PA	R/W/Q	426	50	66,500	0	60000	30000	6500
	RESERVOIR # 30-2	COCALICO TWSP PA	F/W/Q	14	65	13,900	2,144	11480	11480	276
	RESERVOIR # 30-7	BRECKNOCK TWSP PA	W/Q	16	65	11,200	0	10885	10885	315
	RESERVOIR #30-12	ELIZABETH TWSP PA	W/Q	15	65	11,900	0	11524	11524	376
	RESERVOIR # 10	OXFORD PA	F/W/Q/	26	70	21,062	8,418	13644	13644	0
	RESERVOIR # 5-18	MIFFLIN TWSP	F/Q	16	75	11,900	2,100	9595	9595	205
	SWATARA GAP	UNION TWSP PA	W/Q	169	80	10,200	0	10200	6900	0
	RESERVOIR #21-8	MORELAND TWSP PA	F/W/Q	52	150	26,750	5,750	20530	20530	470
	132 MUNCY CREEK	TIVOLI PA	R/W	79	163	62,000	0	61500	30750	500
	RESERVOIR # 022-3	MIFFLIN TWSP PA	F/W/Q	36	170	13,600	5,680	7692	7692	228
	RESERVOIR# 08-4	HARVEY CREEK	F/W/Q	20	180	10,244	2,665	7406	7406	173
	RESERVOIR #38-5	BENTON TWSP	F/W/Q	37	215	15,400	5,975	9005	9005	420
	RESERVOIR#011-9	WAPPASENING CREEK	W/Q	54	295	10,800	0	10474	10474	326
	NY 85 WELTONVILLE	WELTONVILLE NY	F/R	77	305	64,500	5,000	59500	0	0
NON-FED	14					349,956	37,732	303,435	179,885	9,789
	28					4,275,551	1,155,127	3083,035	1540,035	38,389

TABLE 3(ATTACHMENT A)

SUSQUEHANNA RIVER BASIN
EXISTING RESERVOIR PROJECTS
ASSUMING 20% OF CONSERVATION STORAGE
AVAILABLE FOR LOW FLOW AUGMENTATION

CATEGORY	NAME OF PROJECT	ALLOCATED CONSERVATION STORAGE (AC-FT)	COMMITTED LFA STORAGE (AC-FT)	REMAINING CONSERVATION STORAGE (AC-FT)	20% OF REMAINING STORAGE FOR LFA (AC-FT)	10% LOSSES (AC-FT)	NET STORAGE AVAILABLE (AC-FT)
FED	INDIAN ROCK	0	0	0	0	0	0
	RAYSTOWN	514,000	0	514,000	102,800	10280	92,520
	FOSTER SAYERS	28,800	0	28,800	5,760	576	5,184
	STILLWATER	343	0	343	68	6	62
	ALVIN R BUSH	1,745	0	1,745	349	34	315
	CURWENSVILLE	9,540	0	9,540	1,908	190	1,718
	COWANESQUE	32,600	25,600	7,000	1,400	140	1,260
	TIOGA-HAMMOND	18,350	0	18,350	3,670	367	3,303
	WHITNEY POINT	12,500	0	12,500	2,500	250	2,250
	ALMOND	915	0	915	183	18	165
	EAST SIDNEY	3,500	0	3,500	700	70	630
FED	11	622293	25,600	596693	119,338	11,931	107,407
NON-FED	MARBURG	53,100	4,600	48,500	9,700	970	8,730
	DEHART RES	23,600	23,600	0	0	0	0
	SHAWNEE DAM	3,750	0	3,750	750	75	675
	LITTLE PINE CREEK	1,100	0	1,100	220	22	198
	PIKES CREEK	10,556	10,556	0	0	0	0
	HARVEYS LAKE	23,900	0	23,900	4,780	478	4,302
	GLENDALE	25,300	0	25,300	5,060	506	4,554
	LACKAWANNA	14,200	0	14,200	2,840	284	2,556
	CLARENCE F WALKER	2,753	0	2,753	550	55	495
	GEORGE B STEVENSON	2,000	0	2,000	400	40	360
	STILL CREEK	11,587	11,587	0	0	0	0
	COLLIERSVILLE DAM	10,300	0	10,300	2,060	206	1,854
	OTSEGO	39,800	12,360	27,440	5,488	548	4,940
NON-FED	13	221946	62,703	159243	31,848	3,184	28,664
	24	844239	88,303	755936	151,186	15,115	136,071

TABLE 4(ATTACHMENT A)

SUSQUEHANNA RIVER BASIN
POTENTIAL RESERVOIR PROJECTS
ASSUMING 20% OF CONSERVATION STORAGE
AVAILABLE FOR LOW FLOW AUGMENTATION

CATEGORY	NAME OF PROJECT	ALLOCATED CONSERVATION STORAGE (AC-FT)	COMMITTED LFA STORAGE (AC-FT)	REMAINING CONSERVATION STORAGE (AC-FT)	20% OF REMAINING STORAGE FOR LFA (AC-FT)	10% LOSSES (AC-FT)	NET STORAGE AVAILABLE (AC-FT)
FED	SHADY GROVE	59,300	0	59,300	11,860	1186	10,674
	* KEATING	1,200,000	600,000	600,000	120,000	12000	108,000
	SINNEMAHONING	146,000	73,000	73,000	14,600	1460	13,140
	* TOWANDA	97,000	48,500	48,500	9,700	970	8,730
	FABIUS	20,850	10,425	10,425	2,085	208	1,877
	MUD CREEK	27,500	13,750	13,750	2,750	275	2,475
	GREAT BEND	990,000	495,000	495,000	99,000	9900	89,100
	GENEGANTSLET	0	0	0	0	0	0
	FIVEMILE CREEK	32,600	16,300	16,300	3,260	326	2,934
	SOUTH PLYMOUTH	20,850	10,425	10,425	2,085	208	1,877
	* EAST GUILFORD	103,500	51,750	51,750	10,350	1035	9,315
	COPES CORNER	0	0	0	0	0	0
	WEST ONEONTA	0	0	0	0	0	0
	* DAVENPORT CENTER	82,000	41,000	41,000	8,200	820	7,380
FED	14	2779600	1,360,150	1419450	283,890	28,388	255,502
NON-FED	10 CONEWAGO	60,000	30,000	30,000	6,000	600	5,400
	RESERVOIR # 30-2	11,480	11,480	0	0	0	0
	RESERVOIR # 30-7	10,885	10,885	0	0	0	0
	RESERVOIR #30-12	11,524	11,524	0	0	0	0
	RESERVOIR # 10	13,644	13,644	0	0	0	0
	RESERVOIR # 5-18	9,595	9,595	0	0	0	0
	SWATARA GAP	10,200	6,900	3,300	660	66	594
	RESERVOIR #21-8	20,530	20,530	0	0	0	0
	132 MUNCY CREEK	61,500	30,750	30,750	6,150	615	5,535
	RESERVOIR # 022-3	7,692	7,692	0	0	0	0
	RESERVOIR# 08-4	7,406	7,406	0	0	0	0
	RESERVOIR #38-5	9,005	9,005	0	0	0	0
	RESERVOIR#011-9	10,474	10,474	0	0	0	0
	NY 85 WELTONVILLE	59,500	0	59,500	11,900	1190	10,710
NON-FED	14	303435	179,885	123550	24,710	2,471	22,239
	28	3083035	1,540,035	1543000	308,600	30,859	277,741

*These projects were identified as reasonable and implementable projects.

TABLE 5(ATTACHMENT A)

SUSQUEHANNA RIVER BASIN
EXISTING RESERVOIR PROJECTS
SUMMARY
MAXIMUM STORAGE AVAILABLE

CATEGORY	NAME OF PROJECT		COMMITTED LFA STORAGE (AC-FT)	50% USE OF CONSERVATION STORAGE (AC-FT)	3-INCH MAX FLOOD CONTROL STORAGE (AC-FT)	MAXIMUM STORAGE AVAILABLE (AC-FT)
FED	INDIAN ROCK		0	0	11,673	11,673
	RAYSTOWN		0	231,300	85,047	316,347
	FOSTER SAYERS		0	12,960	14,377	27,337
	STILLWATER		0	154	5,090	5,244
	ALVIN R BUSH		0	785	33,406	34,191
	CURWENSVILLE		0	4,293	50,515	54,808
	COWANESQUE		23,040	3,150	7,830	34,020
	TIOGA-HAMMOND		0	8,258	38,134	46,392
	WHITNEY POINT		0	5,625	29,904	35,529
	ALMOND		0	412	4,294	4,706
	EAST SIDNEY		0	1,575	12,322	13,897
FED		11	23,040	268512	292,592	584,144
NON-FED	MARBURG		4,140	21,825	0	25,965
	DEHART RES		21,240	0	0	21,240
	SHAWNEE DAM		0	1,688	6,232	7,920
	LITTLE PINE CREEK		0	495	0	495
	PIKES CREEK		9,501	0	0	9,501
	HARVEYS LAKE		0	10,755	0	10,755
	GLENDALE		0	11,385	8,267	19,652
	LACKAWANNA		0	6,390	0	6,390
	CLARENCE F WALKER		0	1,239	5,373	6,612
	GEORGE B STEVENSON		0	900	31,451	32,351
	STILL CREEK		10,429	0	0	10,429
	COLLIERSVILLE DAM		0	4,635	0	4,635
	OTSEGO		11,124	12,348	0	23,472
NON-FED		13	56,434	71660	51,323	179,417
		24	79,474	340172	343,915	763,561

TABLE 6(ATTACHMENT A)

SUSQUEHANNA RIVER BASIN
POTENTIAL RESERVOIR PROJECTS
SUMMARY
MAXIMUM STORAGE AVAILABLE

CATEGORY	NAME OF PROJECT	COMMITTED LFA STORAGE (AC-FT)	50% USE OF CONSERVATION STORAGE (AC-FT)	3-INCH MAX FLOOD CONTROL STORAGE (AC-FT)	MAXIMUM STORAGE AVAILABLE (AC-FT)
FED	SHADY GROVE	0	26,685	0	26,685
	KEATING	540,000	270,000	360	810,360
	SINNEMAHONING	65,700	32,850	76,308	174,858
	TOWANDA	43,650	21,825	8,651	74,126
	FABIUS	9,383	4,691	3,820	17,894
	MUD CREEK	12,375	6,188	0	18,563
	GREAT BEND	445,500	222,750	0	668,250
	GENEGANTSLET	0	0	13,505	13,505
	FIVEMILE CREEK	14,670	7,335	6,703	28,708
	SOUTH PLYMOUTH	9,383	4,691	7,098	21,172
	EAST GUILFORD	46,575	23,288	0	69,863
	COPES CORNER	0	0	17,129	17,129
	WEST ONEONTA	0	0	15,508	15,508
	DAVENPORT CENTER	36,900	18,450	16,720	72,070
FED	*14	1,224,136	638753	165,802	2,028,691
NON-FED	10 CONEWAGO	27,000	13,500	0	40,500
	RESERVOIR # 30-2	10,332	0	0	10,332
	RESERVOIR # 30-7	9,797	0	0	9,797
	RESERVOIR #30-12	10,372	0	0	10,372
	RESERVOIR # 10	12,280	0	3,835	16,115
	RESERVOIR # 5-18	8,636	0	0	8,636
	SWATARA GAP	6,210	1,485	0	7,695
	RESERVOIR #21-8	18,477	0	0	18,477
	132 MUNCY CREEK	27,675	13,838	0	41,513
	RESERVOIR # 022-3	6,923	0	0	6,923
	RESERVOIR# 08-4	6,666	0	0	6,666
	RESERVOIR #38-5	8,105	0	54	8,159
	RESERVOIR#011-9	9,427	0	0	9,427
	NY 95 WELTONVILLE	0	26,775	0	26,775
NON-FED	14	161,900	55598	3,889	221,387
	28	1,386,036	694351	169,691	2,250,078

TABLE 7(ATTACHMENT A)

POTOMAC RIVER BASIN
PERTINENT DATA FOR EXISTING RESERVOIRS

CAT	NAME OF PROJECT		LOCATION OF PROJECT	PROJECT PURPOSES	DRAIN AREA (SQ MI)	DISTANCE ABOVE MOUTH (MI)	STORAGE AT SPILLWAY (AC-FT)	FLOOD CONTROL STORAGE (AC-FT)	CONSERVE STORAGE (AC-FT)	LFA STORAGE (AC-FT)	INACTIVE STORAGE (AC-FT)
FED	BLOOMINGTON		BLOOMINGTON MD	F/R/W/Q	263	348	130,900	36,200	92000	92000	2700
	SAVAGE		SAVAGE MD	W/Q	105	350	20,000	0	20000	20000	0
FED		2					150,900	36,200	112,000	112,000	2,700
NON-FED	OCCOQUAN		OCCOQUAN VA	W	570	90	33,900	0	31600	31600	2300
	LAKE MANASSAS		MANASSAS VA	W	60	130	17,500	0	12700	12700	4800
	SENECA		BOYDS MD	F/R	21	140	16,970	3,920	12350	12350	700
	VEPCO		MT STORM MD	Q	31	375	47,600	0	47600	47600	0
NON-FED		4					115,970	3,920	104,250	104,250	7,800
		6					266,870	40,120	216,250	216,250	10,500

POTOMAC RIVER BASIN
PERTINENT DATA FOR POTENTIAL PROJECTS

CAT	NAME OF PROJECT		LOCATION OF PROJECT	PROJECT PURPOSES	DRAIN AREA (SQ MI)	DISTANCE ABOVE MOUTH (MI)	STORAGE AT SPILLWAY (AC-FT)	FLOOD CONTROL STORAGE (AC-FT)	CONSERVE STORAGE (AC-FT)	LFA STORAGE (AC-FT)	INACTIVE STORAGE (AC-FT)
FED	SIXES BRIDGE		KEYSVILLE MD	R/W	308	195	69,000	0	63000	63000	6000
	NORTH MOUNTAIN		JONES SPGS WVA	R/W	231	230	97,500	0	95500	95500	2000
	SIDELING HILL		BERKELEY SPGS WVA	R/W	104	260	55,000	0	54500	54500	500
	LITTLE CACAPON		PAW PAW WVA	R/W	101	280	53,800	0	53000	53000	800
	TOWN CREEK		OLDTOWN MD	R/W	145	290	58,000	0	57500	57500	500
	VERONA		VERONA VA	R/W	325	395	107,500	0	104000	104000	3500
FED		6					440,800	0	427,500	427,500	13,300
		6					440,800	0	427,500	427,500	13,300

TABLE 8(ATTACHMENT A)

POTOMAC RIVER BASIN
EXISTING RESERVOIR PROJECTS
SUMMARY
MAXIMUM STORAGE AVAILABLE

CATEGORY	NAME OF PROJECT		COMMITTED LFA STORAGE (AC-FT)	50% USE OF CONSERVATION STORAGE (AC-FT)	3-INCH MAX FLOOD CONTROL STORAGE (AC-FT)	MAXIMUM STORAGE AVAILABLE (AC-FT)
FED	BLOOMINGTON		82,800	0	0	82,800
	SAVAGE		18,000	0	0	18,000
FED		2	100,800	0	0	100,800
NON-FED	OCCOQUAN		28,440	0	0	28,440
	LAKE MANASSAS		11,430	0	0	11,430
	SENECA		11,115	0	507	11,622
	VEPCO		42,840	0	0	42,840
NON-FED		4	93,825	0	507	94,332
		6	194,625	0	507	195,132

POTOMAC RIVER BASIN
POTENTIAL RESERVOIR PROJECTS
SUMMARY
MAXIMUM STORAGE AVAILABLE

CATEGORY	NAME OF PROJECT		COMMITTED LFA STORAGE (AC-FT)	50% USE OF CONSERVATION STORAGE (AC-FT)	3-INCH MAX FLOOD CONTROL STORAGE (AC-FT)	MAXIMUM STORAGE AVAILABLE (AC-FT)
FED	SIXES BRIDGE		56,700	0	0	56,700
	NORTH MOUNTAIN		85,950	0	0	85,950
	SIDELING HILL		49,050	0	0	49,050
	LITTLE CACAPON		47,700	0	0	47,700
	TOWN CREEK		51,750	0	0	51,750
	VERONA		93,600	0	0	93,600
FED		6	384,750	0	0	384,750
		6	384,750	0	0	384,750

TABLE 9(ATTACHMENT A)

POTOMAC RIVER BASIN
EXISTING RESERVOIR PROJECTS
ASSUMING 20% OF CONSERVATION STORAGE
AVAILABLE FOR LOW FLOW AUGMENTATION

CATEGORY	NAME OF PROJECT		ALLOCATED CONSERVATION STORAGE (AC-FT)	COMMITTED LFA STORAGE (AC-FT)	REMAINING CONSERVATION STORAGE (AC-FT)	20% OF REMAINING STORAGE FOR LFA (AC-FT)	10% LOSSES (AC-FT)	NET STORAGE AVAILABLE (AC-FT)
FED	BLOOMINGTON		92,000	92,000	0	0	0	0
	SAVAGE		20,000	20,000	0	0	0	0
FED		2	112000	112,000	0	0	0	0
NON-FED	OCCOQUAN		31,600	31,600	0	0	0	0
	LAKE MANASSAS		12,700	12,700	0	0	0	0
	SENECA		12,350	12,350	0	0	0	0
	VEPCO		47,600	47,600	0	0	0	0
NON-FED		4	104250	104,250	0	0	0	0
		6	216250	216,250	0	0	0	0

TABLE 10(ATTACHMENT A)

POTOMAC RIVER BASIN
POTENTIAL RESERVOIR PROJECTS
ASSUMING 20% OF CONSERVATION STORAGE
AVAILABLE FOR LOW FLOW AUGMENTATION

CATEGORY	NAME OF PROJECT		ALLOCATED CONSERVATION STORAGE (AC-FT)	COMMITTED LFA STORAGE (AC-FT)	REMAINING CONSERVATION STORAGE (AC-FT)	20% OF REMAINING STORAGE FOR LFA (AC-FT)	10% LOSSES (AC-FT)	NET STORAGE AVAILABLE (AC-FT)
FED	SIXES BRIDGE		63,000	63,000	0	0	0	0
	NORTH MOUNTAIN		95,500	95,500	0	0	0	0
	SIDELING HILL		54,500	54,500	0	0	0	0
	LITTLE CACAPON		53,000	53,000	0	0	0	0
	TOWN CREEK		57,500	57,500	0	0	0	0
	VERONA		104,000	104,000	0	0	0	0
FED		6	427500	427,500	0	0	0	0
		6	427500	427,500	0	0	0	0

NORFOLK

TABLE 11 (ATTACHMENT A)

PERTINENT DATA FOR PROPOSED RESERVOIRS

RAPPAHANNOCK RIVER BASIN

NAME OF PROJECT	CATEGORY	LOCATION OF PROJECT	PROJECT PURPOSES	DRAINAGE AREA (SQ.MI.)	DISTANCE ABOVE MOUTH (MI.)	STORAGE AT SPILLWAY (AC.FT.)	FLOOD CONTROL STORAGE (AC.FT.)	STORAGE AT MAX. CONSERVA POOL (AC.FT.)	CONSERVA POOL STORAGE (AC.FT.)	INACTIVE STORAGE (AC.FT.)
SALEM CHURCH RESV.	FEDERAL	RAPPAHANNOCK R.	FC, WS, P, R, WQC, SC	[illegible]	113.4	1,048,000	256,000	792,000		
								10% less 79200		
								Net Total 712800		
								Say 713,000 ac-ft		

TABLE 12(ATTACHMENT A)

NORFOLK

PERTINENT DATA FOR PROPOSED RESERVOIRS

JAMES RIVER BASIN

NAME OF PROJECT	CATEGORY	LOCATION OF PROJECT	PROJECT PURPOSES	DRAINAGE AREA (SQ.MI.)	DISTANCE ABOVE MOUTH (MI.)	STORAGE AT SPILLWAY (AC.FT.)	FLOOD CONTROL STORAGE (AC.FT.)	STORAGE AT MAX. POOL CONSERVA. (AC.FT.)	CONSERVA POOL STORAGE (AC.FT.)	INACTIVE STORAGE (AC.FT.)
Buffalo #3	FEDERAL	TYE & JAMES R.	F	406	1.0	350,000	86,478		263,522	
*Genito	FEDERAL	APPOMATTOX R.	F	716	58.9	790,000	152,508		637,492	
*Hipes	FEDERAL	CRAIG CR	F, FC, WQ, R, FWL, ED	327	14.8	305,000	69,651	245,250	235,349	
Roundabout	FEDERAL	RIVANNA R.	F	768	6.0	430,000	163,584		266,416	
*Upper Carterville	FEDERAL	WILLIS R.	F	263	1.5	422,500	56,019		166,481	
								Total	1,769,260	
								10% Losses	176,930	
								Net Total	1,592,330	
								Say	1,592,000 Ac-Ft	

*These projects were identified as reasonable and implementable.

TABLE 13

UNIT COST OF RESERVOIR STORAGE

EXISTING PROJECTS

Project	Cost at Project Completion ($1000)	Mid-Point Construction Period	Cost Updated to April 83 ($1000)	Storage AC FT	Cost Per AC FT
Raystown	$77,409	April 71	$209,004	762,200	$274
Tioga-Hammond	$185,680	April 75	$354,649	125,000	$2,837
Cowanesque	$106,301	January 77	$173,271	89,000	$1,947

Table 14

UNIT COST OF RESERVOIR STORAGE

POTENTIAL PROJECTS

Project	Cost at Oct 77 Prices* ($1000)	Cost Updated to April 1983 ($1000)	Storage (AC FT)	Cost Per AC FT
Mud Creek	$37,400	$56,848	38,000	$1,496
Copes Corner	$43,500	$66,120	37,900	$1,745
Ganeganslet	$46,900	$71,288	30,195	$2,360
West Oneonta	$48,000	$72,960	34,500	[illegible]
East Guilford	$273,000	$414,960	175,000	$2,371
Keating	$812,000	$1,234,240	1,469,000	$840
Sinnemahoning	$313,000	$475,960	409,000	$1,163
Towanda	$61,600	$93,632	125,000	$749

*SOURCE: Susquehanna River Basin Flood Control Review Study, U.S. Army, Corps of Engineers, Baltimore District, August 1980

Table 15

UNIT COST OF RESERVOIR STORAGE

REFORMULATED PROJECTS

Project	Project Allocated Cost at Oct. 81 Prices ($1000)	Project-Modification Cost at Oct. 81 Prices ($1000)	Total Cost ($1000)	Total Cost Updated to April 83 ($1000)	Reallocated Storage AC FT	Cost Per AC FT
Cowanesque	$43,212 1/	$15,971 1/	$59,183	$65,693	25,600	$2,566
Bloomington	$41,736 2/	$3,337 2/	$45,073	$50,031	18,100	$2,764

1/ Cowanesque Lake Reformulation Study, U.S. Army, Corps of Engineers, Baltimore District, October 1981

2/ Metropolitan Washington Area Water Supply Study, Appendix H, Bloomington Lake Reformulation Study, U.S. Army, Corps of Engineers, Baltimore District, September 1983

ATTACHMENT B

CONSERVATION AND DROUGHT EMERGENCY

Conservation and drought emergency are measures which can be employed to supplement streamflows. The potential of these measures was summarized in Chapter II. This attachment is an explanation of the assumptions and methodologies involved in deriving the potential freshwater inflow savings. Costs are also presented for implementation of conservation in major public water supply systems in the Bay drainage basin.

CONSERVATION

Conservation, as it is usually practiced, is oriented to reduction in requirements for withdrawal. Hardware, such as special shower heads and smaller sized toilet tanks are usually installed in public water supply systems to reduce demand. Conservation, as it is used in this analysis, however, refers to the potential for reduction in consumptive losses. Consumptive loss reduction translates directly to increase in streamflow. Both of these objectives (to reduce withdrawal and consumptive losses) are accomplished through the conservation measures presented in this report.

A survey of the literature available on conservation was conducted to define a range of potential savings for each type of water use. The principal source of information for this was the Institute for Water Resources' Publication, Selected Works in Water Supply, Water Conservation and Water Quality Planning, 1981.

For the public-domestic-commercial types of water use, as well as for irrigation and power plant cooling uses, the range of potential savings adopted is as shown in Table 1. The "high" percentage savings was based on the general concensus, within the literature, on the maximum amount of feasible savings. The "low" value was the minimum that could be accomplished that would still be financially feasible. The "medium" level was assumed to be a reasonable middle ground between the two. The medium level was also used in plan formulation as representative of a most efficient, effective and implementable conservation plan.

The water use categories of manufacturing, livestock, and minerals were not examined for purposes of long-term conservation savings because it was felt that returns or benefits would be minimal. Relatively little water could be saved in livestock watering practices and mineral extraction processes. The manufacturing category was not addressed because of the substantial amounts of technology already incorporated in the water use projections for 2020.

TABLE 1
POTENTIAL REDUCTION IN
WITHDRAWALS DUE TO WATER CONSERVATION
(percent)

Conservation Level	Public-Domestic Commercial	Irrigation	Power	Manuf.	Livestock	Minerals
Low	5	10	10	0	0	0
Medium	10	20	20	0	0	0
High	20	30	30	0	0	0

The original consumptive loss information, used in this study to estimate future changes in freshwater inflow, are presented in the Hydrology Appendix. A summary is provided in Tables 2 and 3. The data are presented by Aggregated Subregion, as originally adopted for use in this study from the Second National Water Assessment, U.S. Water Resources Council, 1978. The ASR's are shown in Figure 1. The ASR level of detail was disaggregated to the 21 inflow points for purposes of testing for the Low Freshwater Inflow Test on the hydraulic model. These total withdrawal and consumptive loss data represent the base values to be reduced by the three alternative levels of conservation.

Application of the percentage reductions shown in Table 1, for the three alternative levels of conservation, results in Table 4. The numbers reflect the accumulated reduction in water supply demand for the public-domestic-commercial, irrigation and power cooling water uses. Data were developed only for those inflow points in which at least a 1 mgd savings could be attained.

The subsequent reduction in consumptive losses is shown in Table 5. These data are equivalent to the increases in streamflow that can be expected under the alternative levels of conservation. Flow increases were computed only for inflow points in which at least a 1 mgd increase could be attained.

The above discussions involving conservation measures have been based on average annual data. Differences may occur seasonally, however, especially in areas heavily weighted to water uses such as irrigation. For this reason, the seasonal variation in consumptive loss saving that may occur with a "medium" conservation scenario combined with a drought emergency plan, is presented in Table 6. The most dramatic departures from the average are shown for the Choptank and Chester Rivers in summer. This is due to the heavy amount of irrigation demand in those agricultural areas.

DROUGHT EMERGENCY

A drought emergency scenario was also developed. This was set up to investigate the potential to supplement flows using a drought contingency plan. The assumed percent reductions in withdrawal are shown in Table 7. It is assumed that these measures would be applicable during only six months of the year, June to November.

Savings are shown for all six types of water use considered in this study. A flat 15 percent reduction was assumed feasible for manufacturing, livestock and minerals. Power and irrigation reductions were assumed to be 10 percent above any conservation plan that may be in effect, as described in the previous section. The reduction in demand and consumptive loss for the public-domestic-commercial category was assumed to be 40 percent, regardless of the conservation measures that may be in place (including none).

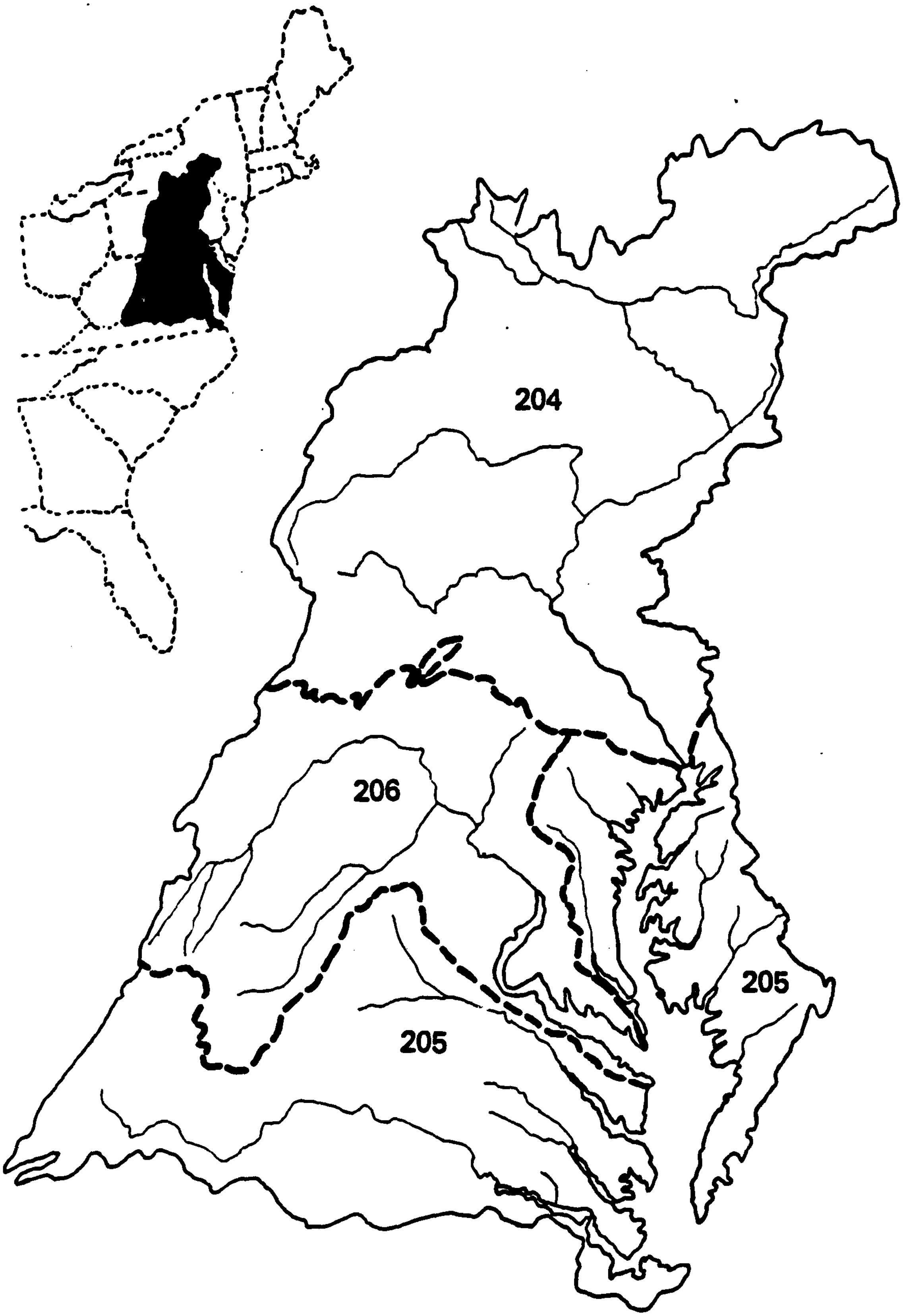

FIGURE 1 (ATTACHMENT B) Aggregated Sub-Regions(ASR's)

TABLE 2
FRESHWATER WITHDRAWALS BY USE FOR 1965 AND 2020
(MGD)

ASR	Area	Inflow Point	P-D-C 1965	P-D-C 2020	Manuf. 1965	Manuf. 2020	Power 1965	Power 2020	Irrigation 1965	Irrigation 2020	Livestock 1965	Livestock 2020	Minerals 1965	Minerals 2020
204	Susquehanna	15	441[1]	811[2]	315	290	550	792	10	31	19	24	70	149
205	Upper and Lower Chesapeake Bay	1	66	130	82	67	0	0	1	1	0	0	2	7
		2	5	12	0	0	0	0	0	0	0	0	6	15
		3	9	17	0	1	0	25	1	3	2	2	2	5
		4	61	128	302	265	0	0	3	8	1	0	15	40
		5	11	31	77	59	0	67	1	2	0	0	1	3
		6	9	19	99	55	0	0	1	2	2	1	1	4
		11	8	26	2	5	0	0	3	4	1	1	5	10
		12	11	24	6	12	0	0	1	1	0	0	1	3
		13	128	216	168	349	0	46	0	0	2	2	6	12
		14	9	23	4	8	0	69	3	4	1	1	4	10
		16	4	7	13	7	0	0	0	8	1	1	2	6
		17	2	5	6	3	0	0	2	36	1	1	0	0
		18	0	0	0	0	0	0	0	0	0	0	0	0
		19	5	10	25	13	0	0	4	81	0	0	0	1
		20	12	22	63	33	0	0	4	6	2	1	2	3
		21	5	9	22	11	0	0	20	11	0	0	1	1
206	Potomac River	7	13	42	0	0	0	0	0	0	0	0	4	15
		8	10	42	0	0	0	0	0	0	0	0	8	35
		9	0	0	0	0	0	0	0	0	0	0	0	0
		10	343	956	224	263	500	170	8	30	12	16	49	198
	Total		1152	2,530	1408	1441	1050	1169	62	228	44	50	179	517

[1] Does not include 26 mgd diversion to Chester, PA.
[2] Does not include projected 57 mgd diversion to Chester, PA.

TABLE 3
CONSUMPTIVE LOSSES BY USE FOR 1965 AND 2020
(MGD)

ASR	Area	Inflow Point	P-D-C 1965	P-D-C 2020	Manuf. 1965	Manuf. 2020	Power 1965	Power 2020	Irrigation 1965	Irrigation 2020	Livestock 1965	Livestock 2020	Minerals 1965	Minerals 2020
204	Susquehanna	15	100[1]	193[2]	46	195	11	528	8	23	19	24	12	29
205	Upper and Lower Chesapeake Bay	1	10	19	6	49	0	0	1	1	0	0	0	1
		2	1	2	0	0	0	0	0	0	0	0	1	2
		3	1	2	0	1	6	17	1	2	2	2	0	1
		4	9	19	22	196	0	0	2	6	1	0	3	5
		5	2	5	26	47	0	45	1	2	0	0	0	0
		6	1	3	7	43	0	0	1	2	2	1	0	1
		11	1	4	0.5	4	0	0	2	3	1	1	1	2
		12	2	4	1	9	0	0	1	0	0	0	0	0
		13	19	32	20	262	0	31	0	0	2	2	1	2
		14	1	3	0.5	6	0	46	2	3	1	1	1	1
		16	0	1	1	5	0	0	0	6	1	1	1	1
		17	0	1	1	2	0	0	2	27	1	1	0	0
		18	0	0	0	0	0	0	0	0	0	0	0	0
		19	1	2	1	10	0	0	3	60	0	0	0	0
		20	2	3	3	25	0	0	3	5	2	1	0	0
		21	1	1	1	9	0	0	15	8	0	0	0	0
206	Potomac	7	1	4	0	0	0	0	0	0	0	0	1	2
		8	1	4	0	0	1	1	0	0	0	0	1	5
		9	0	0	0	0	2	0	0	0	0	0	0	0
		10	35	98	35	195	10	113	6	23	12	16	8	26
	Total		188	400	171	1058	30	783	48	171	44	50	30	78

[1]Includes 26 mgd Diversion to Chester, PA.
[2]Includes 57 mgd Diversion to Chester, PA.

TABLE 4

REDUCTION IN 2020 WITHDRAWAL
DUE TO CONSERVATION
(MGD)

Inflow Point	Year 2020 Withdrawal	Conservation Level Low	Medium	High
15	2097[1]	123	245	451
1	205	6	13	32
2	27	-	-	-
3	53	-	-	-
4	441	7	14	35
5	162	9	17	29
6	82	2	3	6
11	45	1	3	7
12	40	-	-	-
13&14	740	24	48	96
16	29	-	-	-
17	45	4	8	12
18	0	-	-	-
19	104	8	17	27
20	64	2	4	8
21	32	-	-	-
7	57	-	-	-
8	77	-	-	-
9	0	-	-	-
10	1632	68	135	299
Total	5,617*	254	507	1,002

*Total includes only those stations for which conservation plans were developed.

[1] Does not include 57 mgd diversion to Chester, PA.

TABLE 5

REDUCTION IN 2020 CONSUMPTIVE LOSSES
(MGD)

Inflow Point	Year 2020 Consumptive Losses	Conservation Level: Low	Medium	High
15	992[1]	89	178	281
1	70	1	2	6
2	4	-	-	-
3	25	-	-	-
4	226	2	4	8
5	98	8	14	22
6	54	4	5	6
11	14	1	2	3
12	13	-	-	-
13&14	389	13	27	45
16	14	-	-	-
17	30	3	6	10
18	0	-	-	-
19	72	9	17	25
20	34	1	2	3
21	18	-	-	-
7	6	-	-	-
8	10	-	-	-
9	0	-	-	-
10	470	25	50	85
Total	2449*	156	307	494

*Total includes only those stations for which conservation plans were developed.

[1] Does not include 57 mgd loss due to diversion to Chester, PA.

TABLE 6

CONSUMPTIVE LOSS REDUCTIONS FOR MEDIUM CONSERVATION BY SEASON (MGD)

ASR	Inflow Point	Summer Avg	Fall Avg	Winter Avg	Spring Avg	Annual Avg
204	15	202	172	167	172	178
205	1	4	2	1	1	2
	2	-	-	-	-	-
	3	-	-	-	-	-
	4	9	2	1	2	4
	5	16	14	13	14	14
	6	6	5	5	4	5
	11	4	1	0.2	1	2
	12	-	-	-	-	-
	13&14	32	27	25	26	27
	16	-	-	-	-	-
	17	26	0.5	0	1.5	6
	18	-	-	-	-	-
	19	60	2	0	4	17
	20	6	1	0	1	2
	21	-	-	-	-	-
206	7	-	-	-	-	-
	8	-	-	-	-	-
	9	-	-	-	-	-
	10	71	45	40	43	50

TABLE 7

PERCENT REDUCTION IN WITHDRAWAL DUE TO DROUGHT EMERGENCY MEASURES

	Percent Reduction
Public-Domestic-Commercial	40[1]
Irrigation	10[2]
Power	10[2]
Manufacturing	15
Livestock	15
Minerals	15

[1]Total amount, regardless of level of conservation.
[2]Percentage reduction in addition to any adopted conservation measures.

NOTE: These savings are assumed to be applicable only during the months June to November.

The potential reductions in withdrawal and consumptive losses, assumed to be obtainable using drought emergency measures, are shown in Table 8. As noted earlier, the reduction in consumptive loss is equivalent to an increase in streamflow. The very large potential reduction in the Choptank is due to the heavy irrigation water use in that basin.

CONSERVATION IMPLEMENTATION AND COSTS

The potentials of conservation in supplementing streamflows were presented earlier in this attachment. To accomplish these amounts of savings, framework programs were developed to determine the requirements for implementation. The amount of withdrawal reduction for the "low," "medium," and "high" conservation levels were used as targets for the conservation programs. Programs differed among categories but included both structural and nonstructural elements. When available information existed, cost estimates were developed to a level of detail consistent with the overall Chesapeake Bay Study.

P-D-C Conservation

Table 10 presents withdrawal, consumptive loss, and population projections by ASR for the public, domestic and commercial use category. The projections indicate a combined surface water use of 2,586 mgd by 2020 with a projected 2020 loss of 400 mgd. Water use is projected to increase 2.1 times over the base year. The greatest increase is projected to occur in ASR 206, the Potomac Region.

Because the concern is with the year 2020 conditions, Table 9 presents information for that year only. The low, medium and high conservation levels reduced projected withdrawals and consumptive losses by 5 percent, 10 percent and 25 percent, respectively. The amounts of reduction by ASR and by conservation level are shown in Table 10.

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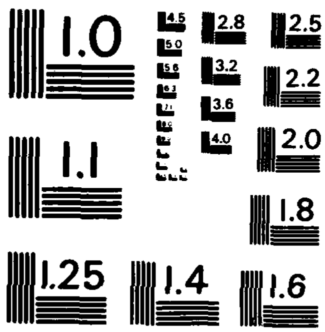
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2.8
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3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

TABLE 8 (ATTACHMENT B)

REDUCTION IN 2020 WITHDRAWAL AND CONSUMPTIVE LOSSES
DUE TO DROUGHT EMERGENCY MEASURES (MGD)

				SUMMER		FALL	
	ASR	INFLOW POINT	BASIN	WITHDRAWAL REDUCTIONS	CONSUMPTIVE LOSS REDUCTIONS	WITHDRAWAL REDUCTIONS	CONSUMPTIVE LOSS REDUCTIONS
204	Susquehanna	15	Susquehanna	364	129	479	141
205	Upper/Lower Chesapeake Bay	1	Nansemond	49	14	65	14
		2	Chickahominy	-	-	-	-
		3	Appomattox	-	-	-	-
		4	James	73	29	100	43
		5	York	21	11	29	14
		6	Rappahannock	12	9	17	11
		11	Patuxent	11	3	13	2.7
		12	Severn	-	-	-	-
		13&14	Upper Western Shore	121	49	65	63
		16	Bohemia	-	-	-	-
		17	Chester	3	9	3.3	0.8
		18	Wye	-	-	-	-
		19	Choptank	28	84	7	3
		20	Nanticoke	12	5	14	6
		21	Pocomoke				
206	Potomac	7	Lower Potomac	-	-	-	-
		8	Occoquan	-	-	-	-
		9	Anacostia	-	-	-	-
		10	Potomac (above Wash., DC)	368	73	478	87
		TOTAL		1072	415	1270	386

TABLE 9

PUBLIC-DOMESTIC-COMMERCIAL
POPULATION, WITHDRAWAL,CONSUMPTIVE LOSSES BY ASR

	1965[1]	1975[2]	1985[2]	2000[2]	2020[3]
ASR 204 - Susquehanna					
Total Population (1000's)	NA	3,676	3,947	4,302	4,668
Use Rate gpcd	NA	158.0	164.4	169.7	173.7
Withdrawal MGD	441	581	649	730	811[4]
Consumptive Loss MGD	74	99	109	121	136[4]
ASR 205 - Upper and Lower Chesapeake					
Total Population (1000's)	NA	4,673	5,136	5,732	6,426
Use Rate (gpcd)	NA	97.1	101.3	103.8	105.5
Withdrawal MGD	345	454	520	595	678
Consumptive Loss MGD	51	67	78	87	101
ASR 206 - Potomac					
Total Population (1000's)	NA	4,113	5,082	6,547	8,453
Use Rate gpcd	NA	117.4	119.6	121.7	123.1
Withdrawal (MGD)	366	483	608	797	1,040
Consumptive Loss MGD	37	49	64	82	106

[1]From NAR Study
[2]Derived from 2nd National Water Assessment

TABLE 10

EFFECTS OF CONSERVATION ON PROJECTED
P-D-C WITHDRAWALS AND CONSUMPTIVE LOSSES

Aggregated Sub Region	2020 Base Condition	Low Conservation (5%)	Medium Conservation (10%)	High Conservation (25%)
ASR 204 - Susquehanna				
Withdrawal	811	770	730	608
Withdrawal Reduction	-	41	81	203
Consumptive Loss	136	129	122	102
Consumptive Loss Reduction	-	7	14	34
ASR 205 - Upper and Lower Chesapeake				
Withdrawal	678	644	610	508
Withdrawal Reduction	-	34	68	170
Consumptive Loss	101	95	92	74
Consumptive Loss Reduction	-	5	8	26
ASR 206 - Potomac				
Withdrawal	1,040	989	937	781
Withdrawal Reduction	-	52	104	260
Consumptive Loss	106	103	96	80
Consumptive Loss Reduction	-	4	11	27
Totals				
Withdrawals	2,530	2,403	2,227	1,897
Withdrawal Reduction	-	127	253	633
Consumptive Loss	343	327	310	256
Consumptive Loss Reduction	-	16	33	87

In an effort to allocate the reductions to a per person basis, each ASR was examined to determine 1980 Standard Metropolitan Statistical Areas (SMSA). The SMSAs were used as a representation of urban population which would be more likely to implement conservation measures (relative to non-urban areas). The proportion of SMSA population totals to basin population totals (ususlly 65-80 percent) could also be viewed as a conservative estimate of the population participation rate basin-wide. Table 11, 1980 SMSA populations by Aggregated Sub Region.

The conservation measures considered for public-domestic-commercial water users are listed in Table 9. A generalized estimate of their reduction capability (water savings) and unit cost is also presented. These estimates were based on literature surveys and results of earlier studies. The information in this table was then used to generate an estimate of costs and water reduction in each of the Aggregated Sub Regions.

For the ASR, the 1980 SMSA population of 3,120,966 is approximately 85 percent of the total Susquehanna Basin population. Applying this factor to 2020 populations shown in Table 9 results in an estimated 2020 SMSA population of 3,968,000. If 3,968,000 people are using water-savings techniques in 2020, each person would have to save about 10 gallons a day to achieve the low conservation scenario "target." This amount would increase to 20 gallons and 50 gallons a day to achieve the medium and high levels of conservation, respectively. Table 13 presents the devices and estimated costs associated with the low, medium and high conservation levels. The high conservation devices are similar to those presented in the other conservation levels, but assumptions concerning reduction capability and device costs differ from those of the other conservation levels.

For ASR 205, the 1980 population of 4,373,302 is approximately 90 percent of the total Chesapeake population. However, to reflect a more conservative estimate, it was assumed that only 75 percent of the projected 2020 population of 6,426,000 would reside in SMSAs. This resulted in a 2020 SMSA population estimate of 4,820,000.

Translating this into reduced water use, each of the 4,820,000 would have to reduce 2020 water use by 7 gallons to realize the low level savings of 34 mgd. This would increase to 14 gallons per person if the medium conservation level was desired. The high level decrease of 170 mgd would mean a per person decrease of about 35 gallons a day. Table 14 presents information on a low, medium and high conservation levels for the Chesapeake Region.

For ASR 206 the 1980 SMSA population of 3,281,108 is about 75 percent of the total Potomac Region population. Applying this percentage to the 2020 populations shown in Table 9 results in an estimated 2020 SMSA population of 6,340,000. If this number of people are using water-saving techniques in 2020, each person would have to save about 8 gallons to achieve the low conservation level reduction of 53 mgd. This would increase to about 17 gallons per person if the medium conservation level is deemed desirable. The 260 mgd decrease "targeted" by the high conservation level translates into a per person water savings of 41 gallons a day. Table 15 presents information for all conservation levels. A summary of the quantity savings and associated costs for each of the conservation levels is found in Table 16.

TABLE 11

BASIN SMSA POPULATIONS
(1980 Preliminary Population)

SMSA	1980 Preliminary Population
ASR 204 - Susquehanna	
Altoona	136,621
Binghamton	301,336
Elmira	97,656
Harrisburg	446,072
Lancaster	362,346
Northeast	640,396
State College	112,760
Williamsport	118,416
Wilmington	524,108
York	381,255
Subtotal	3,120,966
ASR 205 - Chesapeake	
Charlottesville	113,568
Baltimore	2,174,023
Lynchburg	153,260
Newport-Hampton	364,449
Norfolk - VA Beach	806,691
Petersburg - Col. Heights	129,296
Hopewell	
Richmond	632,015
Subtotal	4,373,302
ASR 206 - Potomac	
Washington, D.C.	3,060,240
Cumberland	107,782
Hagerstown	113,086
Subtotal	3,281,108
Total	10,775,376

TABLE 12

CONSERVATION MEASURES, REDUCTION RATES AND ESTIMATED COSTS

Measures	Reduction Rates	Unit Costs
	(Low and Medium Conservation)	
Residential		
Faucet Aerators	1 gpcpd	$3.00
Low Water use Toilets	5 gpcpd	2.50
Showers Aerators/Devices	6 gpcpd	5.00
Nonstructural Behavior Modifications	7 gpcpd	$70,000/3,000,000 persons
Pressure Reducing Valves	2 gpcpd	25.00
Clotheswashers	2 gpcpd	8.00
Dishwashers	2 gpcpd	----
Outdoor Watering	-------	----
System Monitoring/Leak Detection	-------	----
Commercial*		
Faucet Areators	1 gpdpe*	$3.00
Low Water Use Toilets	1.5 pgflush	2.50
Nonstructural Behavior Modification	1.5 gpdpe	$20,000/year
Outdoor Watering	0.5 gpdpe	---
	(High Conservation)	
Residential		
Behavior Modification	9 gpcpd	$90,000/Year
Low Water Use Toilets	12 gpcpd	$60.00
Shower Devices	10 gpcpd	$5.00
Faucet Aerators	2 gpcpd	$3.00
Clotheswashers	3 gpcpd	$8.00
Dishwashers	3 gpcpd	$8.00
Pressure Reducing Valves	3 gpcpd	$25.00
Leak Detection	2 gpcpd	$65.00/mgd saved
Pipe Insulation	3 gpcpd	$57.00
Commercial**		
Faucet Aerators	1 gpcpd**	$3.00
Low Water use Toilets	3 gpcpd	$2.50
Behavior Modification	2.5 gpcpd	$40,000/Year
Outdoor Watering	1.5 gpcpd	--------

*Commercial Savings based on 1,000,000 employees.
**Commercial Savings based on 2,000,000 employees.

TABLE 13

P-D-C CONSERVATION MEASURES FOR
THE SUSQUEHANNA BASIN

Conservation Measures	Persons	Total Reduction (mgd)	1977 Costs
Low Level			
Commercial			
Low Water Use Toilets	1,000,000	1.0	$120,000*
Faucet Aerators	1,000,000	3.0	100,000*
Residential			
Faucet Aerators	3,968,000	3.968	$3,840,000**
Shower Aerators	3,968,000	23.808	6,400,000**
Low Water Use Toilets	3,968,000	19.840	6,400,000**
Sub Total		51.616 mgd	$16,860,000
Medium Level			
Commercial			
Behavior Modification	1,000,000	1.5	$800,000
Outdoor Watering	1,000,000	0.5	--------
Residential			
Behavior Modification	3,968,000	27.776	$3,600,000
Clotheswashers	3,968,000	7.936 mgd	10,240,000
Sub Total (included low level		89.328 mgd	$31,500,000
High Level			
Commercial			
Faucet Aerators	2,000,000	2.0	$240,000*
Low Water Toilets	2,000,000	6.0	240,000*
Behavior Mod.	2,000,000	5.0	1,600,000
Outdoor Watering	2,000,000	3.0	2,040,000
Residential			
Behavior Modification	3,968,000	35.712	$3,600,000
Toilets	3,968,000	47.616	153,600,000**
Shower Devices	3,968,000	39.680	6,400,000**
Faucet Aerators	3,968,000	7.936	3,840,000
Clotheswashers	3,968,000	11.904	10,240,000**
Dishwashers	3,968,000	11.904	10,240,000**
PRV's	3,968,000	11.904	32,000,000**
Leak Detection	3,968,000	7.936	7,531,000
Pipe Insulation	3,968,000	11.904	72,960,000**
Total		202.496 mgd	$302,451,000

*One Unit (Device) per 25 employees - 80,000 units.
**1,280,000 households (3.1 persons per households).

TABLE 14

P-D-C CONSERVATION MEASURES FOR
THE CHESAPEAKE REGION

Conservation Measures	Persons	Total Reduction (mgd)	1977 Costs
Low Level			
Commercial			
Faucet Aerators	1,000,000	1.0	$120,000
Low Water Use Toilets	1,000,000	3.0	100,000
Residential			
Faucet Aerators	4,820,000	4.82	$4,665,000
Shower Aerators/Devices	4,820,000	28.92	7,774,000
Medium Level			
Commercial			
Behavior Modification	1,000,000	1.5	$800,000
Outdoor Watering	1,000,000	0.5	------
Residential			
Low Water Use Toilets	4,820,000	24.1	$7,774,000
Behavior Modifications	4,820,000	33.74	4,440,000
Total (includes low level)		97.58	$25,673,000
High Level			
Commercial			
Faucet Aerators	2,000,000	2.0	$240,000*
Low Water Toilets	2,000,000	6.0	200,000*
Behavior Modification	2,000,000	5.0	1,600,000
Outdoor Watering	2,000,000	3.0	2,040,000
Residential			
Behavior Modification	4,820,000	43.38	$4,440,000
Toilets	4,820,000	57.84	186,581,000
Shower Devices	4,820,000	48.2	7,774,000**
Faucet Aerators	4,820,000	9.64	4,665,000**
Clotheswahsers	4,820,000	(14.46)	12,439,000**
Dishwashers	4,820,000	(14.46)	12,439,000**
PRV's	4,820,000	(14.46)	38,871,000**
Leak Detection	4,820,000	(9.64)	9,154,000**
Pipe Insulation	4,820,000	(14.46)	88,626,000*
Total		175.06 mgd	$205,500,000

*One Unit (Device) per 25 employees - 80,000 units
**1,554,838 households (3.1 per household)

NOTE: Numbers in parentheses represent additional savings achieved if all elements of the program are implemented.

TABLE 15

P-D-C CONSERVATION MEASURES FOR
THE POTOMAC REGION

Conservation Measures	Persons	Total Reduction (mgd)	1977 Costs
Low Level			
Commercial			
Faucet Aerators	1,000,000	1.0	$120,000*
Low Water Use Toilets	1,000,000	3.0	100,000*
Residential			
Faucet Aerators	6,340,000	6.34	$6,135,000**
Shower Aerators/Devices	6,340,000		10,226,000**
Low Water Use Toilets	6,340,000	31.7	10,226,000**
Total		42.04	26,807,000
Medium Level			
Commercial			
Behavior Modificatin	1,000,000	1.5	$8000,000
Outdoor Watering	1,000,000	0.5	---------
Residential			
Behavior Modification	6,340,000	44.38	$5,832,000
Total (includes low level)		88.42	33,439,000
High Level			
Commercial			
Faucet Aerators	2,000,000	2.0	$240,000*
Low Water Toilets	2,000,000	6.0	200,000*
Behavior Modification	2,000,000	5.0	1,600,000
Outdoor Watering	2,000,000	3.0	2,040,000
Residential			
Behavior Modification	6,340,000	57.06	*5,832,000**
Toilets	6,340,000	78.08	245,419,000**
Shower Devices	6,340,000	63.4	10,225,800**
Faucet Aerators	6,340,000	12.68	6,135,000
Clotheswashers	6,340,000	19.02	16,361,000**
Dishwashers	6,340,000	19.02	16,361,000
PRV's	6,340,000	(19.02)	(51,129,000)*
Leak Detection	6,340,000	(12.68)	(12,031,400)
Pipe Insulation	6,340,000	(19.02)	(116,574,000)
Total		263.26 mgd	302,374,000

*One Unit (Device) per 25 employees - 80,000 units
**2,045,161 households (3.1 persons per household)

NOTE: Numbers in parentheses represent additional savings achieved if all elements of the program are implemented.

/c |

TABLE 16

SUMMARY OF PUBLIC-DOMESTIC-COMMERCIAL
CONSERVATION MEASURES

	Low		Medium		High	
Region	Quantity[1]	Cost[2]	Quantity[1]	Cost[2]	Quantity[1]	Cost[2]
ASR 204 - Susquehanna	51.62	$16,860,000	89.33	$31,500,000	202.50	$302,451,000
ASR 205 - Chesapeake	37.74	$12,659,000	97.58	$25,673,000	175.06	$205,500,000
ASR 206 - Potomac	42.04	$26,807,000	88.42	$33,439,000	263.26	$302,374,000
Total	169.44	$56,326,000	313.37	$90,642,000	640.82	$810,325,000

[1]Quantity shown is in millions of gallons per day (mgd).
[2]Cost estimates are based on 1977 dollar estimates.

AGRICULTURAL IRRIGATION CONSERVATION

Another category of water use identified as part of the Chesapeake Bay Study was that of agricultural irrigation. Based on the NAR Study information and results of the Second National Assessment, 1965, estimated conditions were identified and projections of irrigation water use made to the year 2020.

Water withdrawals for irrigation are projected to increase from 63 mgd (average annual) to 250 mgd (average annual) in the year 2020 — an amount almost 4 times the 1965 base condition. In absolute terms, consumptive losses are projected to increase 169 mgd in 2020, slightly more than 3.5 times the 1965 estimated amount. However, relative to withdrawals, consumptive losses decrease from 77 percent of the total 1965 withdrawals to 75 percent of the total 2020 withdrawals.

Because irrigation does not occur 12 months a year, distribution factors were used to allocate the average annual demands to monthly values for the five-month period of May to September. The 1965 and 2020 monthly demands are shown in Table 17.

Shown in Table 18 are the 2020 conditions by ASR with the various levels of conservation also reflected. The low, medium and high conservation levels were assumed to reduce projected withdrawals and consumptive losses by 10 percent, 20 percent and 30 percent respectively.

TABLE 17

CHESAPEAKE BAY DRAINAGE BASIN
IRRIGATION WITHDRAWALS AND CONSUMPTIVE LOSSES
(mgd)

Month	1965 Withdrawals	1965 Consumptive Losses	2020 Withdrawals	2020 Consumptive Losses
May	45.5	34.2	166.5	124.9
June	133.4	100.0	488.4	366.4
July	321.3	241.0	1,176.2	882.2
August	225.9	169.4	827.1	620.4
September	12.2	9.1	44.4	33.3

As presented in detail in the Chesapeake Bay Future Conditions Report, the Economic Research Service of the Department of Agriculture conducted a thorough evaluation of farm acreage for the study area extending approximately to the head of tide of the Bay tributaries. In addition to projecting farm acreage to the year 2020, the ERS also projected acres of irrigated farmland. Starting with a 1969-1970 estimate of 58,633 irrigated acres, the ERS projected 147,000 acres to be irrigated by 1980 increasing to 377,000 acres in the year 2020. This information is presented in Table 19. The 2020 total of 377,100 acres represents a 643 percent increase over the total of 58,633 irrigated acres, or an average annual increase of 12.6078 percent per year based on 51 years.

To consider the conservation required per acre, basin-wide estimates of irrigated acreage were desirable. In 1979 the Interagency Task Force Report on Irrigation Water Use and Management provided estimates of acreage irrigated by state as of 1977. After adjusting the tri-state total to account for portions not draining into the Bay an estimate of 106,400 irrigated acres was obtained. This 1977 estimate was then extrapolated, and an estimate of 577,000 acres was obtained to represent acreage that will be irrigated in the Chesapeake Bay drainage area in 2020.

One additional adjustment was made to the 2020 acreage estimate. Because the 2020 irrigation withdrawal estimates represent surface water use and the 577,000 acres represent acreage irrigated by groundwater and surface water, the assumption was made that in the year 2020 (based on existing trends) approximately 65 percent of the acreage would be irrigated from groundwater sources. The remaining 35 percent, or 202,000 acres, was assumed to be irrigated by surface withdrawals. Taking this amount of acreage and the conservation reductions presented in Table 18, Table 20 was compiled. The mgd reductions were converted to acre-feet and then allocated to the applicable acreage. These computations indicate that anywhere from 0.12 acre-feet to 0.38 acre-feet a year would have to be conserved per acre to achieve the indicated conservation reductions.

TABLE 18

EFFECTS OF CONSERVATION ON PROJECTED IRRIGATION WITHDRAWAL AND CONSUMPTIVE LOSSES (MGD)

Aggregated Sub Regions	2020 Condition	Low Conservation (10%)	Medium Conservation (20%)	High Conservation (30%)
ASR 204 - Susquehanna				
Withdrawal	31	28	25	22
Withdrawal Reduction	-	3	6	9
Consumptive Loss	23	20	17	14
Consumptive Loss Reduction	-	3	6	9
ASR 205 - Upper and Lower Chesapeake				
Withdrawal	167	150	134	117
Withdrawal Reduction	-	17	33	50
Consumptive Loss	125	100	95	82
Consumptive Loss Reduction	-	25	30	43
ASR 206 - Potomac				
Withdrawal	30	27	24	21
Withdrawal Reduction	-	3	6	9
Consumptive Loss	23	19	16	13
Consumptive Loss Reduction	-	4	7	10
Totals				
Withdrawal	228	205	183	160
Withdrawal Reduction	-	23	45	68
Consumptive Loss	171	148	128	109
Consumptive Loss Reduction	-	23	43	62

TABLE 19
ESTIMATES OF 2020 IRRIGATED ACREAGE
IN BAY REGION

	1980	2000	2020
Delaware	67,000	77,000	91,000
Maryland	39,500	97,600	217,800
Virginia	40,500	71,400	68,300
TOTAL	147,000	246,000	377,100

TABLE 20
SURFACE IRRIGATION WITHDRAWAL REDUCTIONS

	Low Conservation (10%)	Medium Conservation (20%)	High Conservation (30%)
Withdrawals (mgd)	205 mgd	183 (mgd)	160 mgd
Reduction (mgd)	23	45	68
Reduction (acre-feet)	70.58/day	138.10/day	208.68/day
Irrigated Acres	202,000	202,000	202,000
Acre-Feet/Year	25,761.7	50,406.5	76,168.2
Reduction Acre/Year	0.128 ac-feet	0.25 ac-feet	0.38 ac-feet

It was beyond the scope of the Bay Study to pursue a detailed analysis of irrigation-related conservation measures and costs. However, means do exist for controlling, reducing, or conserving the use of water as it relates to crop production. Similar to the P-D-C category, both structural measures and non-structural measures could be implemented. Some of these methods are presented in Table 21.

Factors that should be considered before any measure is implemented include soil type and percolation, crops to be raised and the timing of their moisture requirements, crop yield, and application rates. In addition to using the methods listed in Table 21, it is also conceivable that some amount of irrigable acreage could be removed from mechanical systems to rely only on natural moisture accumulation.

This analysis of irrigation has not presented any specific measures or structural programs for acheving the low, medium and high conservation levels. However, the reduction amounts indicative of the low and medium levels are considered to be reasonable and capable of being achieved if implemented in an appropriate manner. The reductions reflective of the high conservation level are not viewed as unachievable, but may require measures and techniques that could be considered state-of-the art. For this reason, program implementation would probably be somewhat less certain.

TABLE 21

IRRIGATION WATER CONSERVATION MEASURES

Structural Conservation Methods

Sprinkler	Seepage Control
Drip Irrigation	System Automation
On-Farm Reuse (tailwater recapture)	Use of Groundwater

Nonstructural Methods

Existing System Improvement	Better Flow Measurement
Irrigation Scheduling (by crop and weather)	Laser Leveling
Good and Proper Drainage (may involve some structural work)	Water Allocation Program
	Education/Technology Transfer
Rainfall Utilization	Terrace Farming
Weed and Phreatophyte Control	No-Till farming
Leveling and Reorienting Fields	Covering Reservoirs and Ditches
Acid/gypsum or Other Soil Treatment	Deficit Irrigation
Wastewater Reuse	Soil Moisture Monitoring

POWER GENERATION CONSERVATION

In Table 3 withdrawals related to power generation were shown to approximate 1050 mgd in 1965, with consumptive losses of 30 mgd. Projections of water use by the Bay Study Group indicate a 2020 demand of 1,169 mgd in ASRs 204, 205 and 206, with ASR 204 - SUSQUEHANNA projected to be the biggest user. Consumptive losses were projected to be 528 mgd for the Susquehanna in the year 2020.

Table 22 presents the projected conditions by ASR and the impact of various levels of conservation on the 2020 conditions. The low, medium and high conservation levels were assumed to reduce projected withdrawals for power requirements by 10 percent, 20 percent and 30 percent respectively. In terms of quantity, withdrawals would be decreased by 117 mgd if low level conservation is employed. This reduction would increase to 234 mgd if the medium conservation level were used and 351 if the high level of conservarion were used.

Conservation programs for achieving the various levels of reduction were not developed for this analysis. Neither were device or implementation costs estimated. It was considered beyond the scope of the Chesapeake Bay Study to develop programs and cost information relative to implementation. However, measures and methods do exist which could impact directly or indirectly on the use of water for power generation. These measures could be aimed directly at the power process or indirectly at the rate of energy consumption. Using less energy would curtail the amount of water required. A list of some of the potential ways to reduce water use in the power generation category is presented in Table 23.

The analysis of power generation water use has not presented any specific measures or structural programs for achieving the low, medium and high conservation levels. However, the reduction amounts indicative of low and medium levels are considered to be reasonable and capable of being achieved if implemented in an appropriate manner. The reductions reflective of the high conservation level are not viewed as unachievable, but may require measures and techniques that could be considered state-of-the-art. For this reason, program implementation would probably be somewhat less certain.

TABLE 22

EFFECT OF CONSERVATION ON PROJECTED POWER WITHDRAWALS

Aggregated Sub-Regions (ASR)	2020 Condition	Low Conservation (10%)	Medium Conservation (20%)	High Conservation (30%)
ASR 204 - Susquehanna				
Withdrawals	792 mgd	712.8 mgd	633 mgd	544.4 mgd
Consumption	528 mgd	499 mgd	158.4 mgd	237.6 mgd
Mgd Reduction	-------	79.2 mgd	158.4 mgd	237.6 mgd
ASR 205 - Chesapeake				
Withdrawals	207 mgd	186.3 mgd	165.6 mgd	144.9 mgd
Consumption	139 mgd	121 mgd	103 mgd	84 mgd
Mgd Reduction	-------	20.7 mgd	41.4 mgd	62.1 mgd
ASR 206 - Potomac				
Withdrawals	170 mgd	153 mgd	136 mgd	119 mgd
Consumption	113 mgd	96 mgd	79 mgd	62 mgd
Mgd Reduction	-------	17 mgd	34 mgd	51 mgd
Total				
Withdrawals	1,169 mgd	1,052.1 mgd	935.2 mgd	818.3 mgd
Consumption	780 mgd	666 mgd	552 mgd	436 mgd
Mgd Reduction	---------	16.9 mgd	233.8 mgd	350.7 mgd

TABLE 23

WATER CONSERVATION MEASURES
FOR POWER GENERATION

Public Education	Brown-Outs
Media Advertising	Technological Advances
Rate-Making Policy Changes	Fluidized-Bed Boilers[1]
Use of Fossil Fuels	Combined Cycle Plant[2]

[1] Fluidized - bed boilers allow lime to be added to coal in the boiler, thereby eliminating the need for sulfur removal equipment and associated water use.

[2] Combined - cycle plants use combustion-turbine units to improve the overall thermal efficiency of the cycle. Consumptive use of water is smaller per unit of capacity than for other types of thermal generation.

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ATTACHMENT C

DEVELOPMENT OF STORAGE REQUIREMENTS FOR LOW FLOW SUPPLEMENTATION

During the problem identification phase of the study, it was determined that Future Drought and in some cases Base Drought salinities would adversely affect the biota in Chesapeake Bay. A series of alternatives were developed to alleviate these damages. One of these alternatives is the supplementation of freshwater inflows through releases from reservoir storage. These alternatives are oriented to achieving predetermined salinity goals during specific seasons of the year. The purpose of this attachment is to display the methodology that was used in determining the amount of reservoir storage required to meet these goals. Although there are many possible conditions, the analysis presented here will concentrate on the amount of storage required to provide sufficent releases of water to decrease salinities from Future Drought to Base Drought levels. The methodology for other conditions would be similar.

The first step in the selected methodology involves defining the amount of time required for the Bay to achieve a given salinity regime after an inflow change has been made. The assumption is that there exists a period of time required for the salinities of the Bay to adjust to new flow conditions and that freshwater inflow must be supplemented during this period if target salinities are to be met during the season of focus. Fortunately the hydraulic model tests provided a set of data which could be used to gain insight to this adjustment period. Both the Base and Future hydraulic model tests were designed to simulate four years of drought freshwater inflows followed by four repetitions of a year of average inflows.

Antecedent conditions for the first average year was a drought hydrograph, while the third average year antecedent conditions was an average hydrograph. Consequently the salinities were higher at the beginning of the first average year than they were at the beginning of the third average year. Even though the hydrographs for the two average years are identical, a considerable period of time lapsed before similar salinity time histories were achieved. To determine this adjustment period, salinity time histories for the first and third years were plotted for various stations throughout the Bay and its tributaries. From the plots the adjustment period was bracketed, beginning at the start of the year and ending at the point where the first and third year salinities were approximately identical. The resulting time period varied from a relatively short time for the upper reaches of the Bay and tributaries to a much longer time period as one progressed downstream. Consequently, a range was used for all further calculations. The time histories used in the analysis are presented on Figure 1 through 4.

The time periods identified by the above methods were the antecedent periods for the season of concern. This antecedent period was then added to the number of days within the season of concern, yielding the total time that flow supplementation would be required for each of the seasons. The storage for each of the seasons was determined by multiplying these total days by the average daily consumptive losses, see Figure 5 for a graphical representation. The time frames used in calculating storages are pesented on Table 1, while Table 2 presents the resulting storages required to achieve and maintain Base Drought salinity levels, for one season of the year during a recurrence of the Future Drought.

TABLE 1
NUMBER OF DAYS REQUIRED FOR SEASONAL
FLOW SUPPLEMENTATION

River	Antecedent time (days)	Total Time (days)
Susquehanna	90 - 150	180 - 240
Potomac	90 - 150	180 - 240
James	60 - 90	150 - 180
Rappahannock	90 - 150	180 - 240
York	60 - 90	150 - 180

Implementation of the reservoir storage alternative could be quite complex. The storages presented in Table 2 are for the unique situation when the freshwater inflow hydrograph is identical to the Future Drought and the goal is to return to Base Drought salinity levels. Because of the importance of antecendent conditions, any other sequence of flows would result in different salinity time histories. Consequently, the amount of water that must be added to the system to achieve the salinity goals would probably be different from those required under Future Drought hydrographic conditions. For this reason, it is not possible to specify the minimum levels of freshwater inflow required to meet salinity goals. Rather, the amount of water that would be released from storage must be computed as a function of real time salinities and projected estimates of anticipated freshwater inflows over the subsequent seasons.

A sophisticated computer model could be used to determine the amount of water that would be released from storage under other flow conditions and/or to provide more accurate estimates for the flow supplementation plans presented above. An appropriate computer model would be a two dimensional, laterally averaged, or a three dimensional hydrodynamic, computer model capable of operating with variable freshwater inflows for a number of model years. The computer model should also be applicable to a partially mixed estuary, capable of simulating a variable tide history, and accommodating several major rivers simultaneously.

In order to successully implement a computer model, real time monitoring of the Bay would be required, first to determine if a drought exists and second to provide the antecedent freshwater inflows and salinities as well as other necessary hydrodynamic parameters.

TABLE 2

STORAGE NEEDED TO ACHIEVE BASE DROUGHT

River	Season	Incremental Consumptive Losses (cfs)	Storages (in 1000 ac-ft)	
			Low	High
Susquehanna (IFP 15) 1/	Spring	1197	424	569
	Summer	1362	459	598
	Fall	1215	462	605
	Winter	1167	428	588
Potomac (IFP's 8, 9, 10)	Spring	532	187	252
	Summer	694	219	281
	Fall	551	224	287
	Winter	506	190	272
James (IFP's 2, 3, 4)	Spring	310	92	110
	Summer	352	100	119
	Fall	313	98	119
	Winter	304	92	111
Rappahannock (IFP 6)	Spring	58	21	28
	Summer	65	22	29
	Fall	58	22	29
	Winter	57	21	28
York (IFP 5)	Spring	107	32	38
	Summer	115	33	40
	Fall	107	33	40
	Winter	104	32	38

1/ IFP: Inflow Point

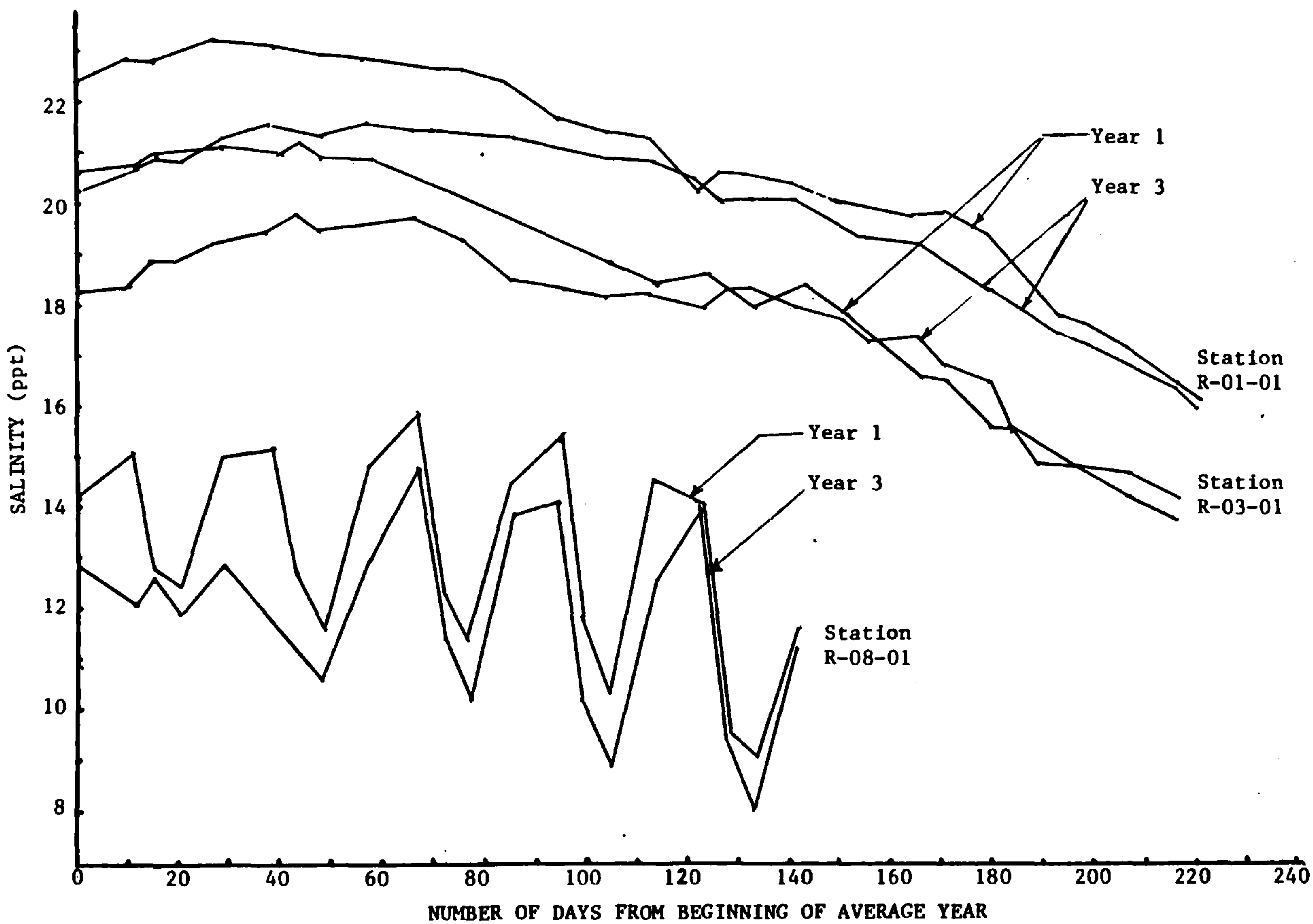


FIGURE 1 (ATTACHMENT C) AVERAGE YEARS 1&3 SALINITY HISTORIES FOR SELECTED RAPPAHANNOCK RIVER STATIONS

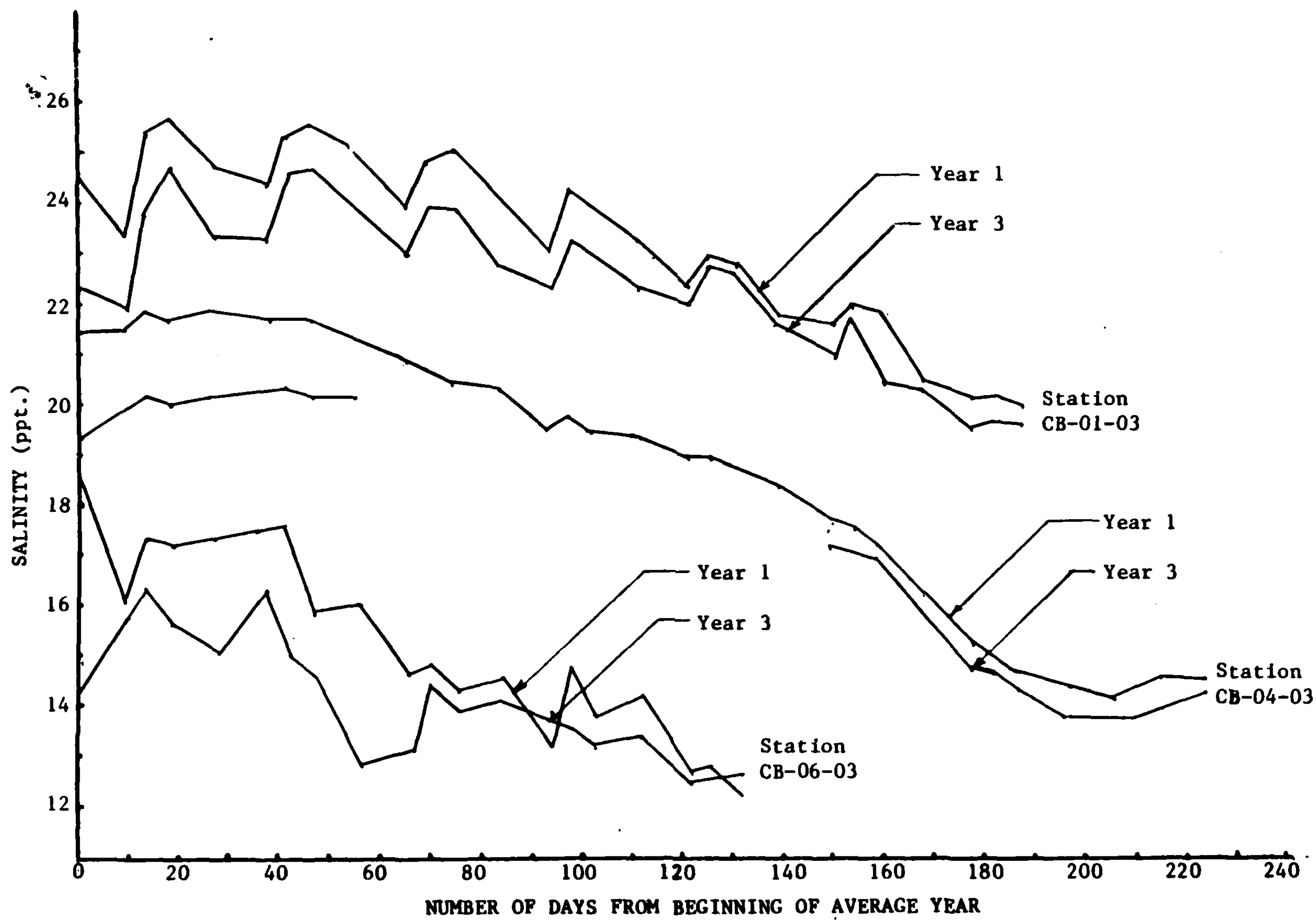


FIGURE 2 (ATTACHMENT C) AVERAGE YEARS 1&3 SALINITY HISTORIES FOR SELECTED CHESAPEAKE BAY STATIONS

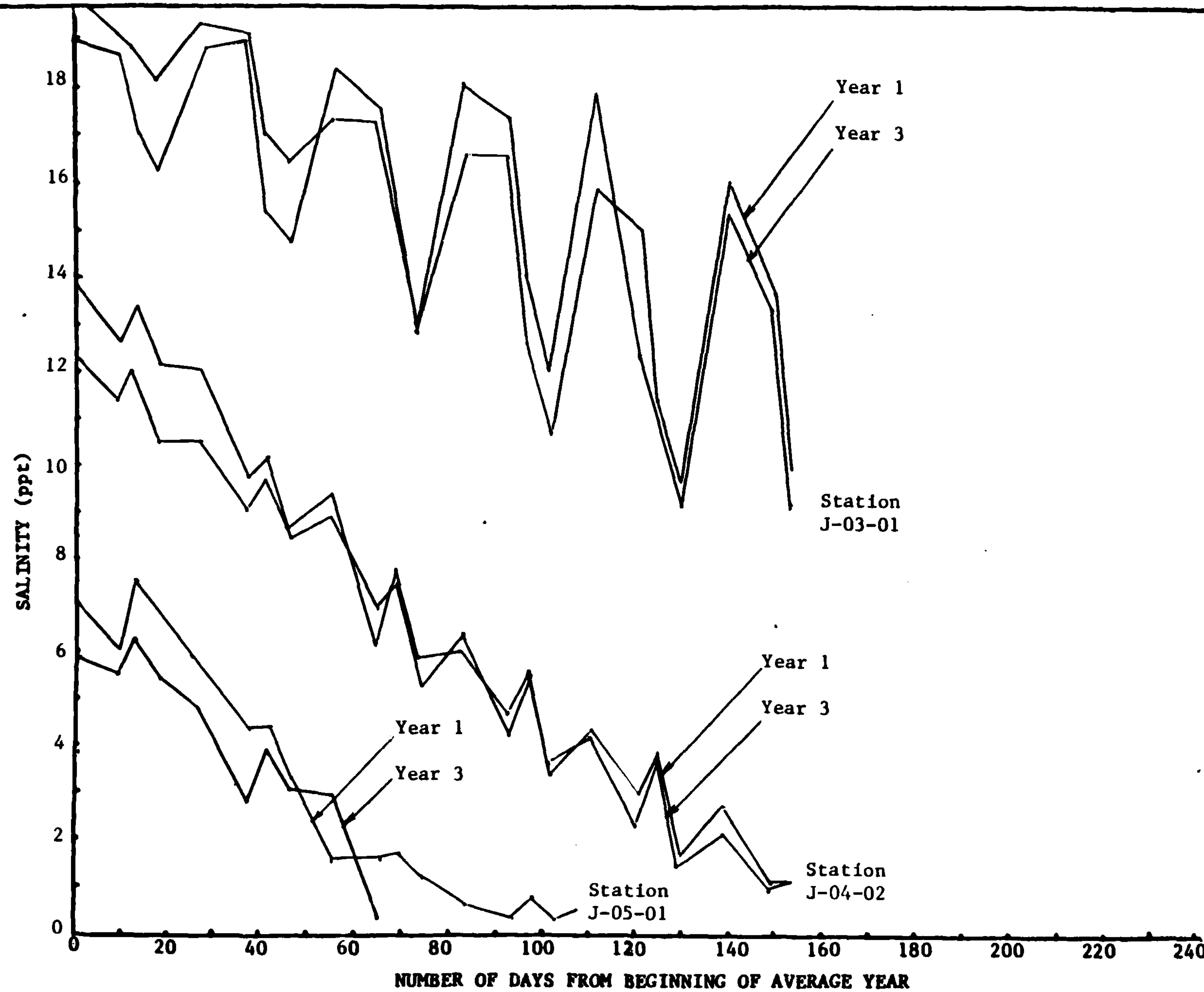


FIGURE 3 (ATTACHMENT C) AVERAGE YEARS 1&3 SALINITY HISTORIES FOR SELECTED JAMES RIVER STATIONS

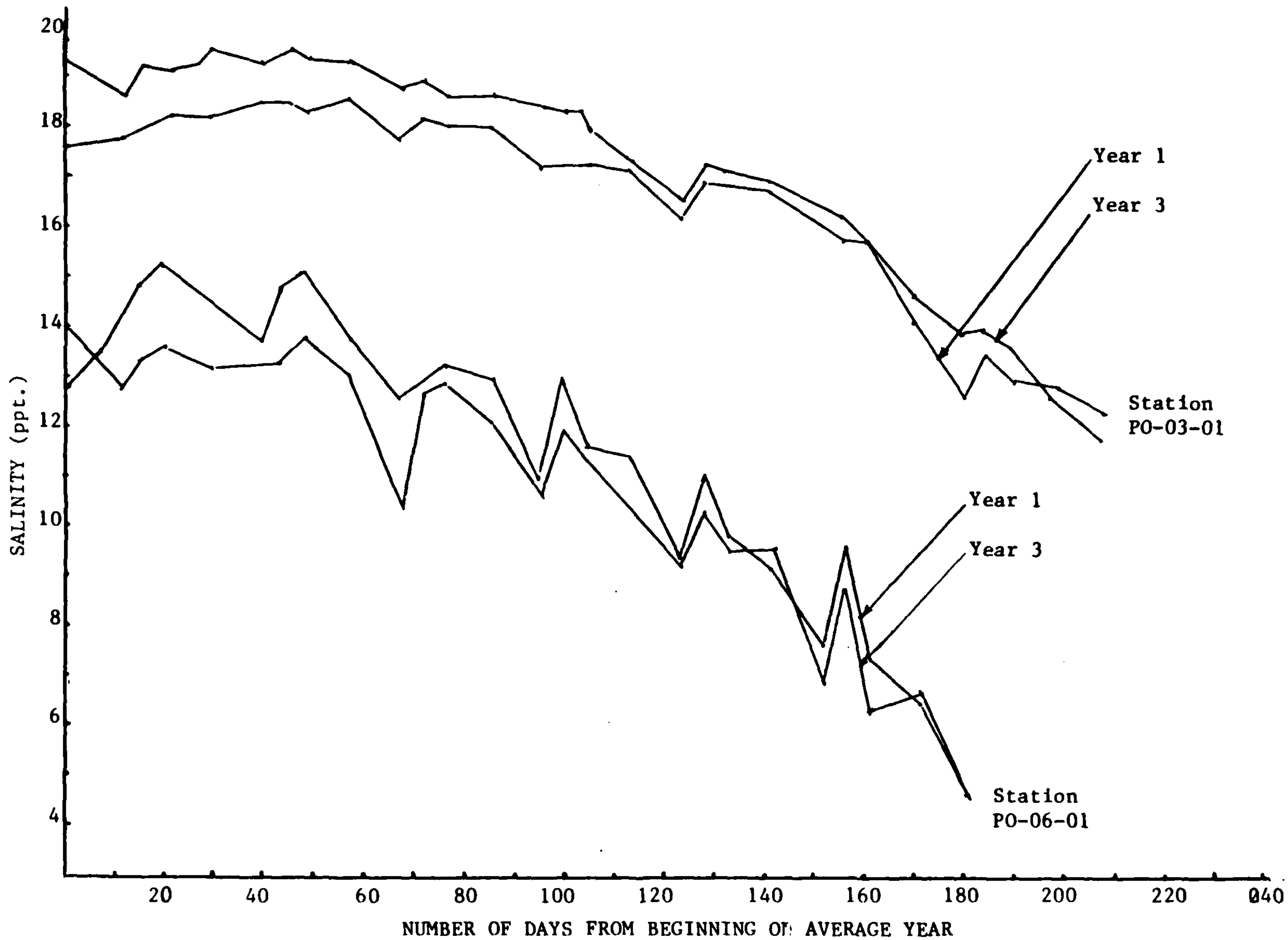


FIGURE 4 (ATTACHMENT C) AVERAGE YEARS 1&3 SALINITY HISTORIES FOR SELECTED POTOMAC RIVER STATIONS

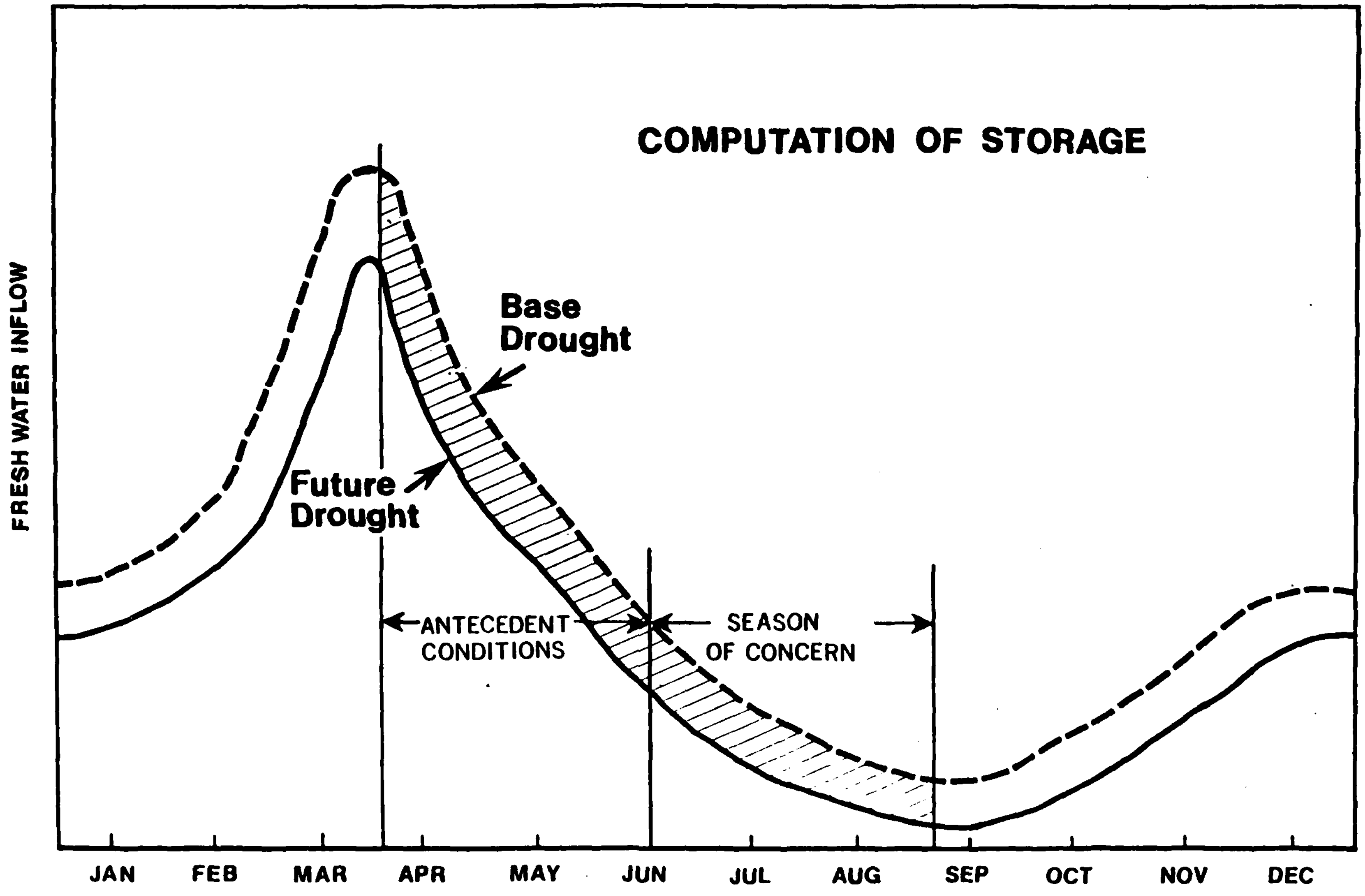


FIGURE 5 (ATTACHMENT B-3) GRAPHICAL REPRESENTATION OF STORAGE CALCULATIONS

PLATES

The following Plates (I through XIV) are maps of the Chesapeake Bay. They indicate, for specified organisms, the location of the isohalines used as principal criteria in defining the goals of the various plans developed in this report. Since criteria evolved with the planning process, multiple maps, are present for some organisms, indicating alternative and changing planning goals. Principal reasons for different maps for the same species may be:

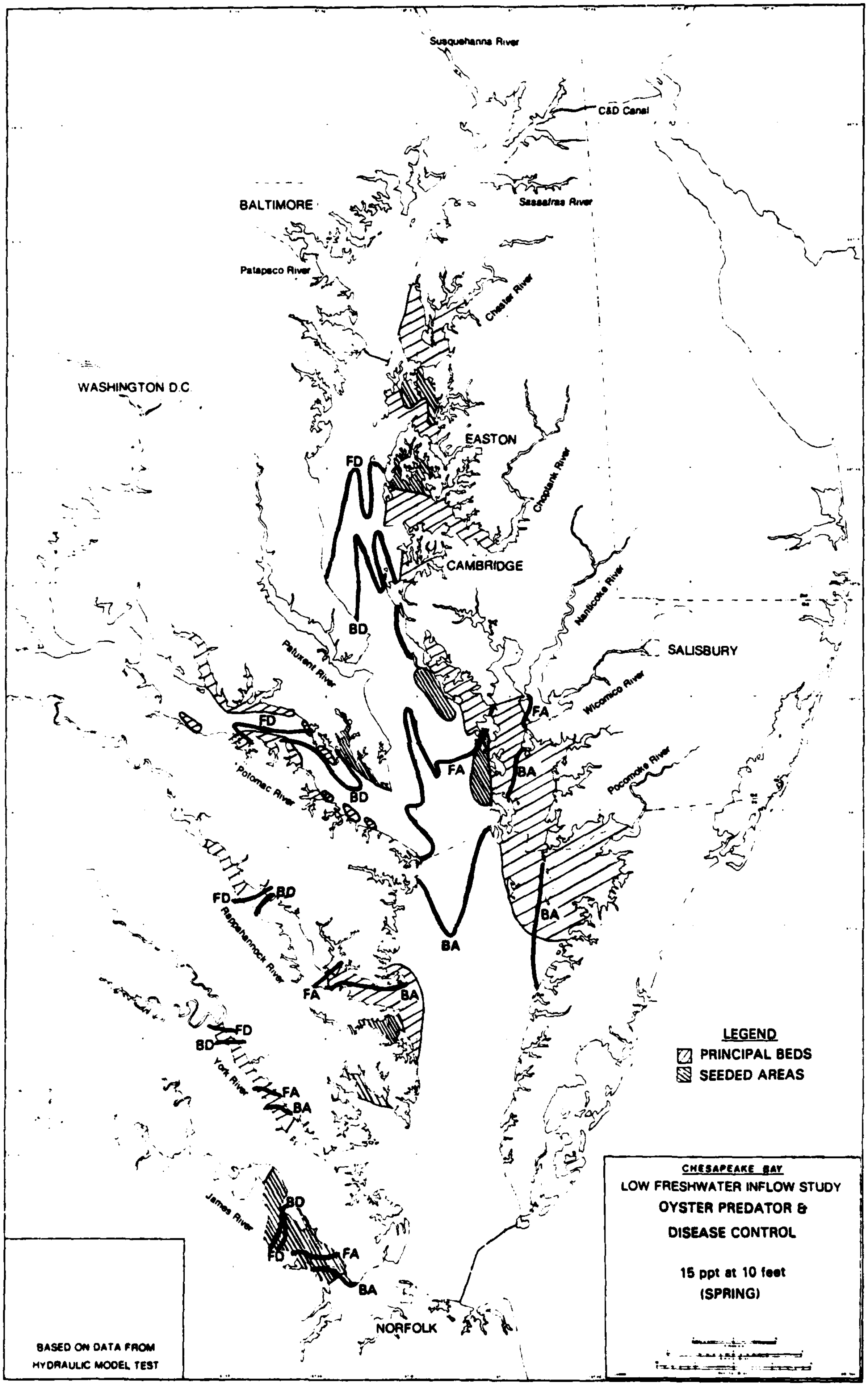
a) different goals for drought events than for the long-term average

b) goals for a year-round average salinity, as opposed to a seasonal goal

c) changes in criteria (for example oyster from spring to summer)

The lines shown on the maps indicate the locations of the isohalines during the noted seasons (or year-round average), as derived from the hydraulic model test. The abreviations are defined as follows:

BA: Base Average
FA: Future Average
BD: Base Average
FD: Future Drought
BYA: Base Yearly Average
FYA: Future Yearly Average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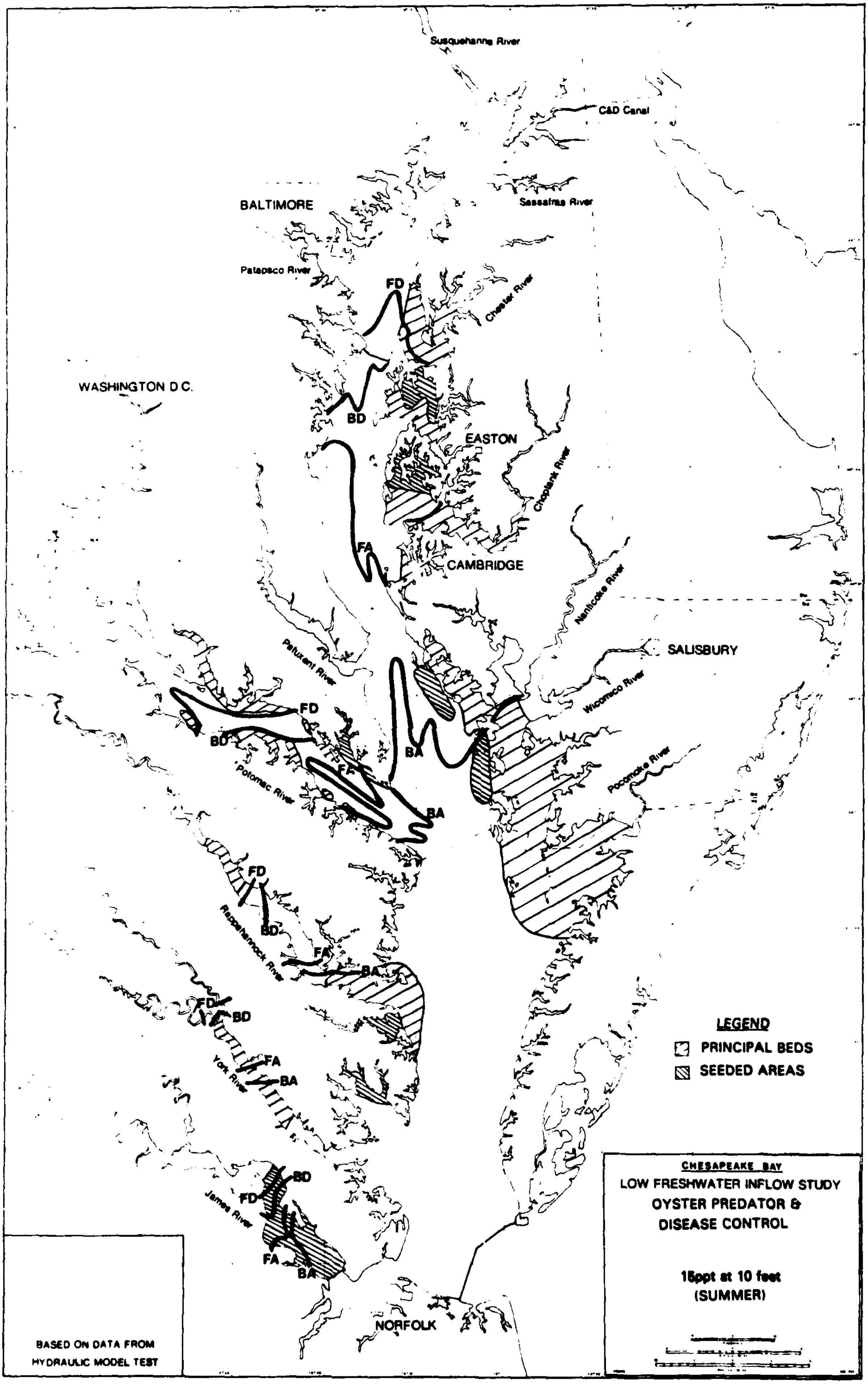
Wicomico River
Potomac River
Pocomoke River
Rappahannock River
York River
James River
NORFOLK
FD
BD
FA
BA
LEGEND
PRINCIPAL BEDS
SEEDED AREAS
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
OYSTER PREDATOR &
DISEASE CONTROL
15 ppt at 10 feet
(SPRING)
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE B-1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York River
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SEEDED AREAS
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James River
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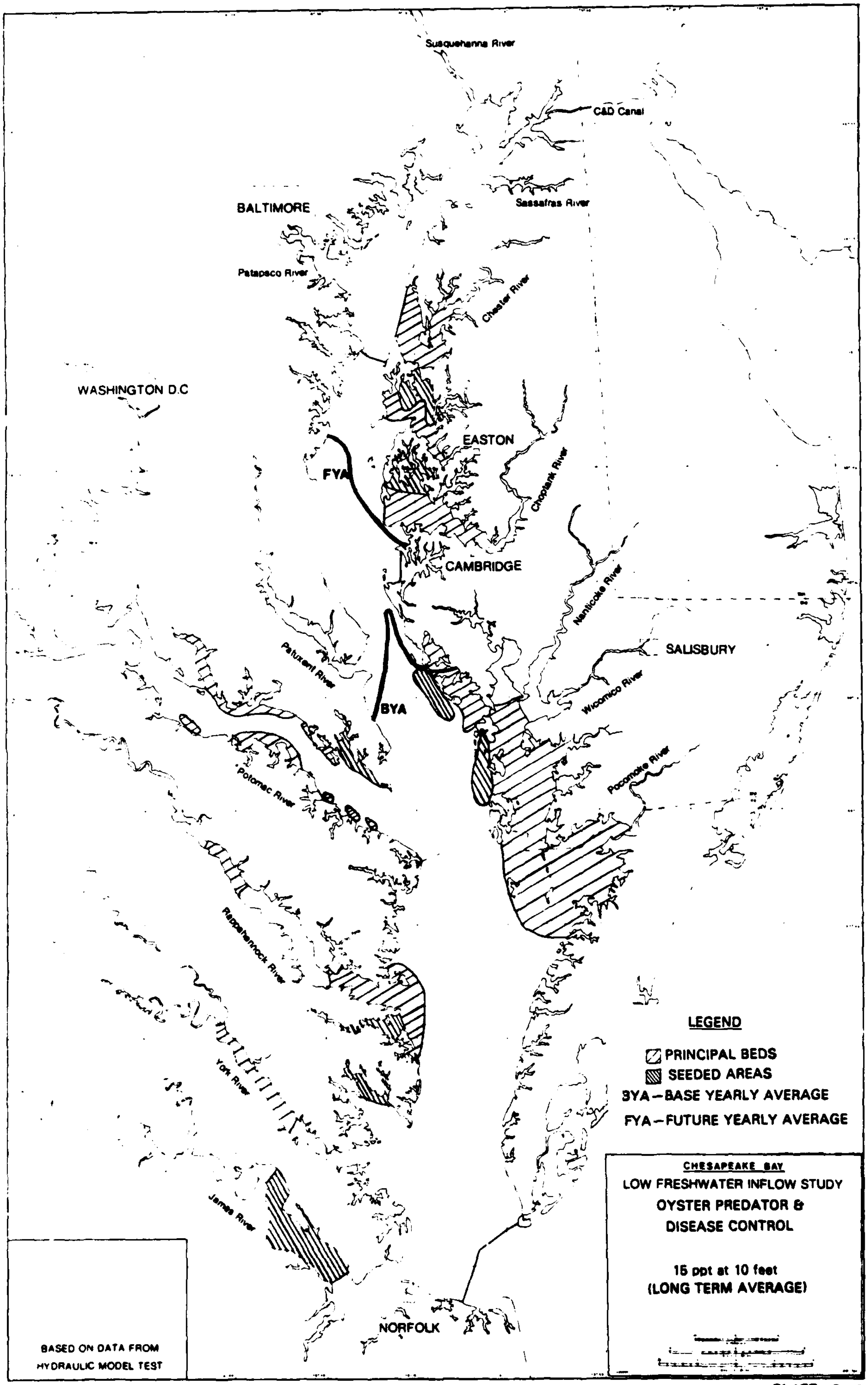
NORFOLK
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
OYSTER PREDATOR &
DISEASE CONTROL
15ppt at 10 feet
(SUMMER)
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE B–2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Rappahannock River
York River
James River
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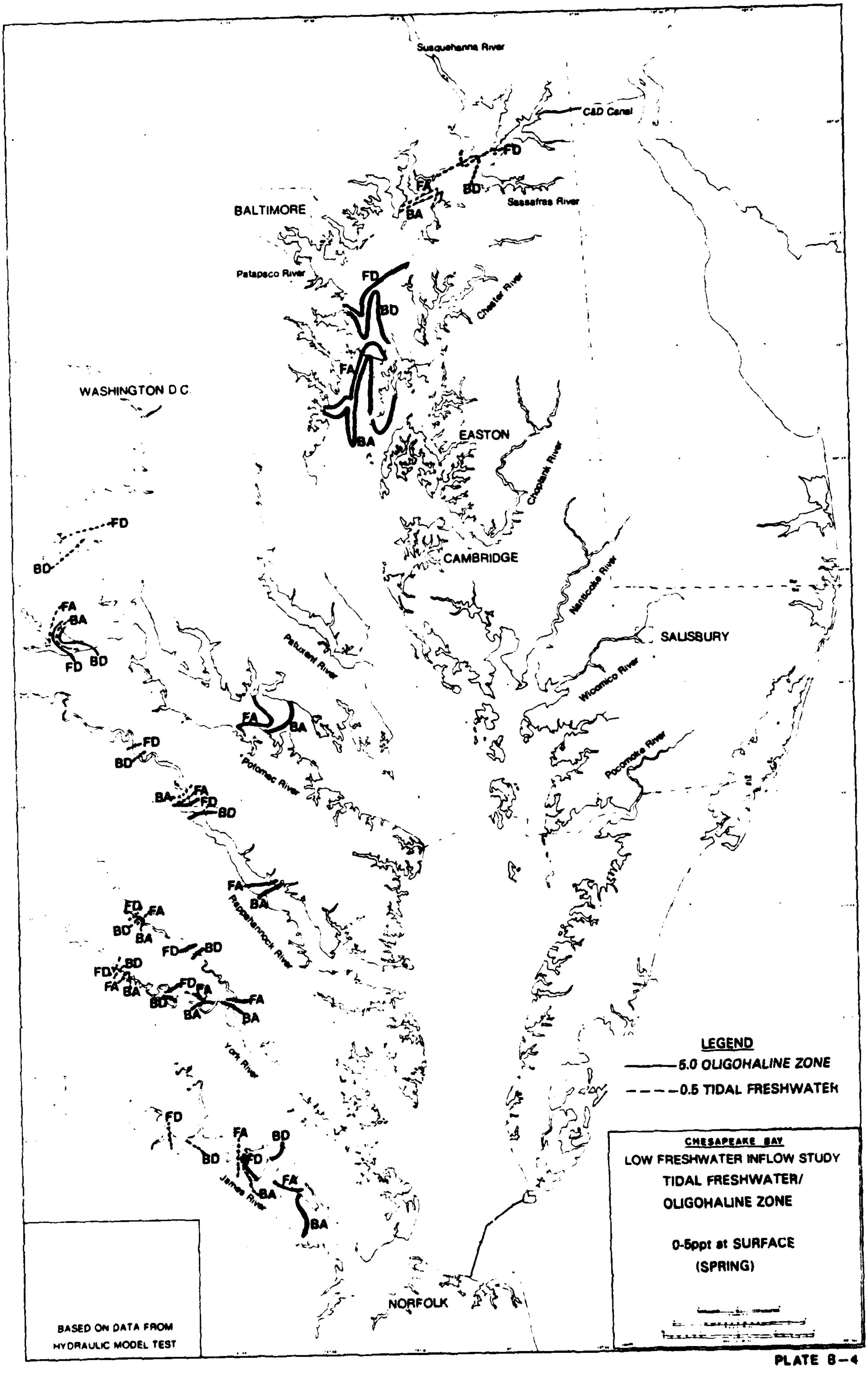
LEGEND
PRINCIPAL BEDS
SEEDED AREAS
BYA—BASE YEARLY AVERAGE
FYA—FUTURE YEARLY AVERAGE
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
OYSTER PREDATOR & DISEASE CONTROL
15 ppt at 10 feet
(LONG TERM AVERAGE)
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE 8-3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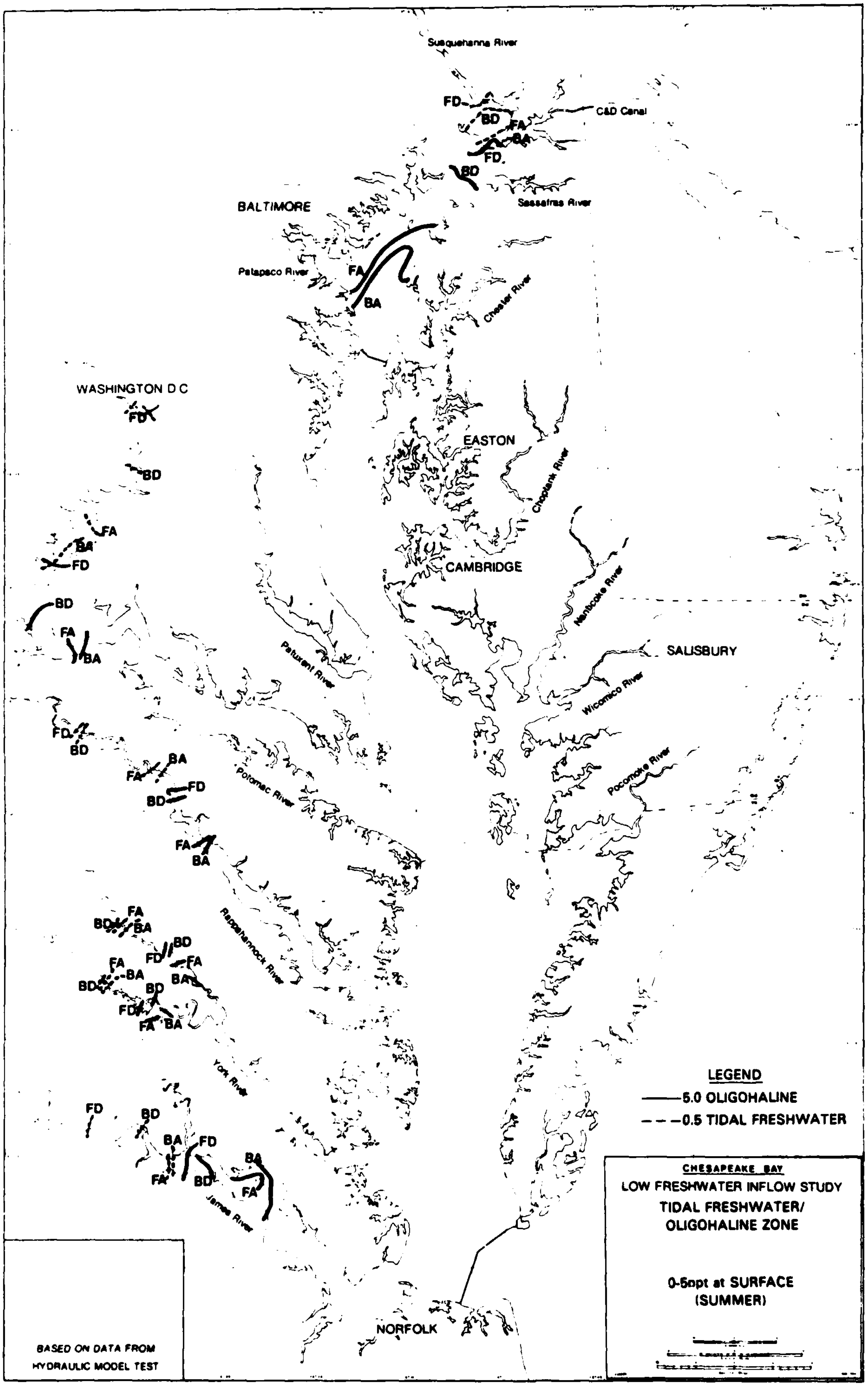
0.5 TIDAL FRESHWATER
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
TIDAL FRESHWATER/
OLIGOHALINE ZONE
0-5ppt at SURFACE
(SPRING)
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE B-4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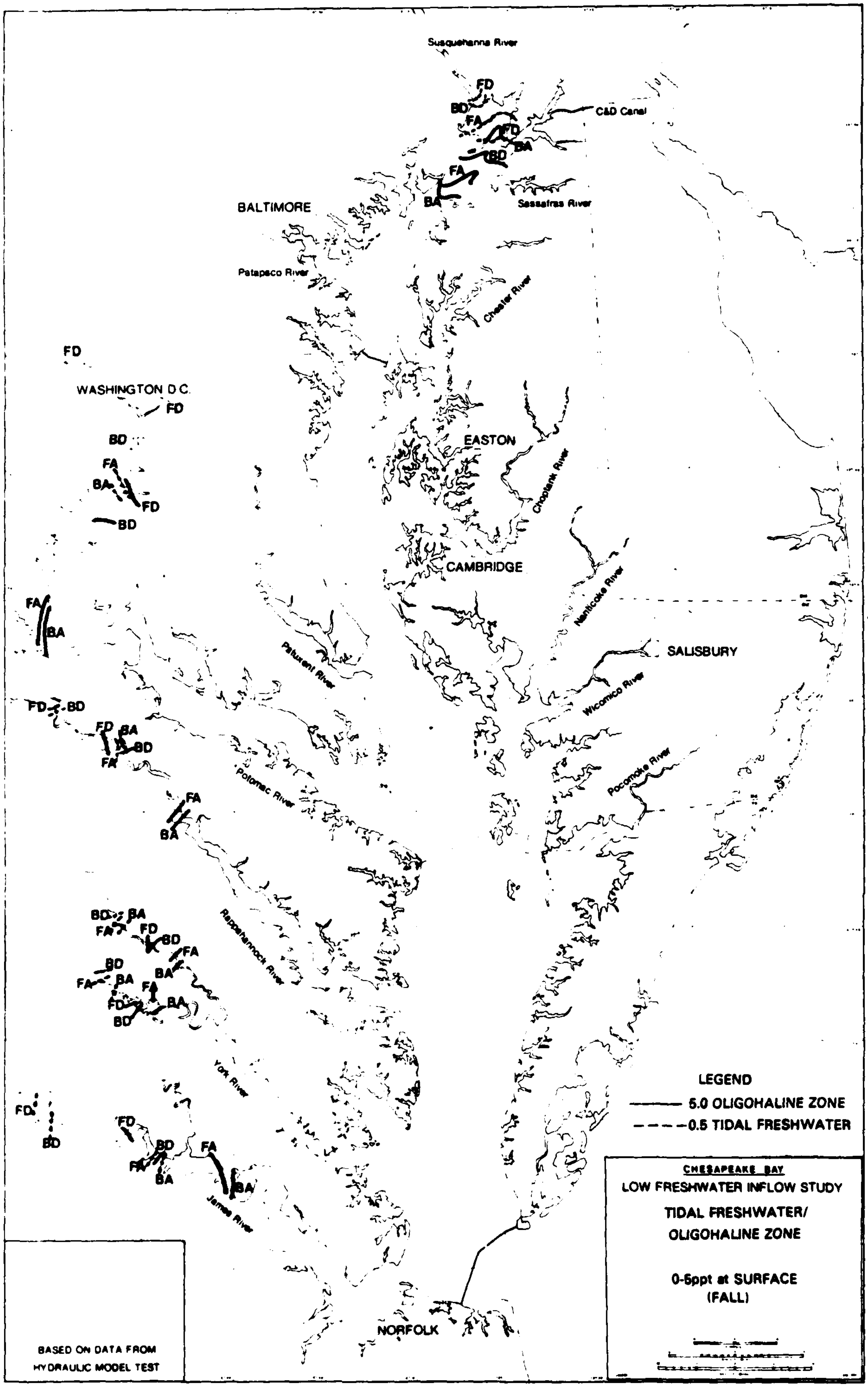
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
TIDAL FRESHWATER/
OLIGOHALINE ZONE
0-5ppt at SURFACE
(SUMMER)
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE B–5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Patuxent River
Wicomico River
Potomac River
Pocomoke River
Rappahannock River
York River
James River
NORFOLK
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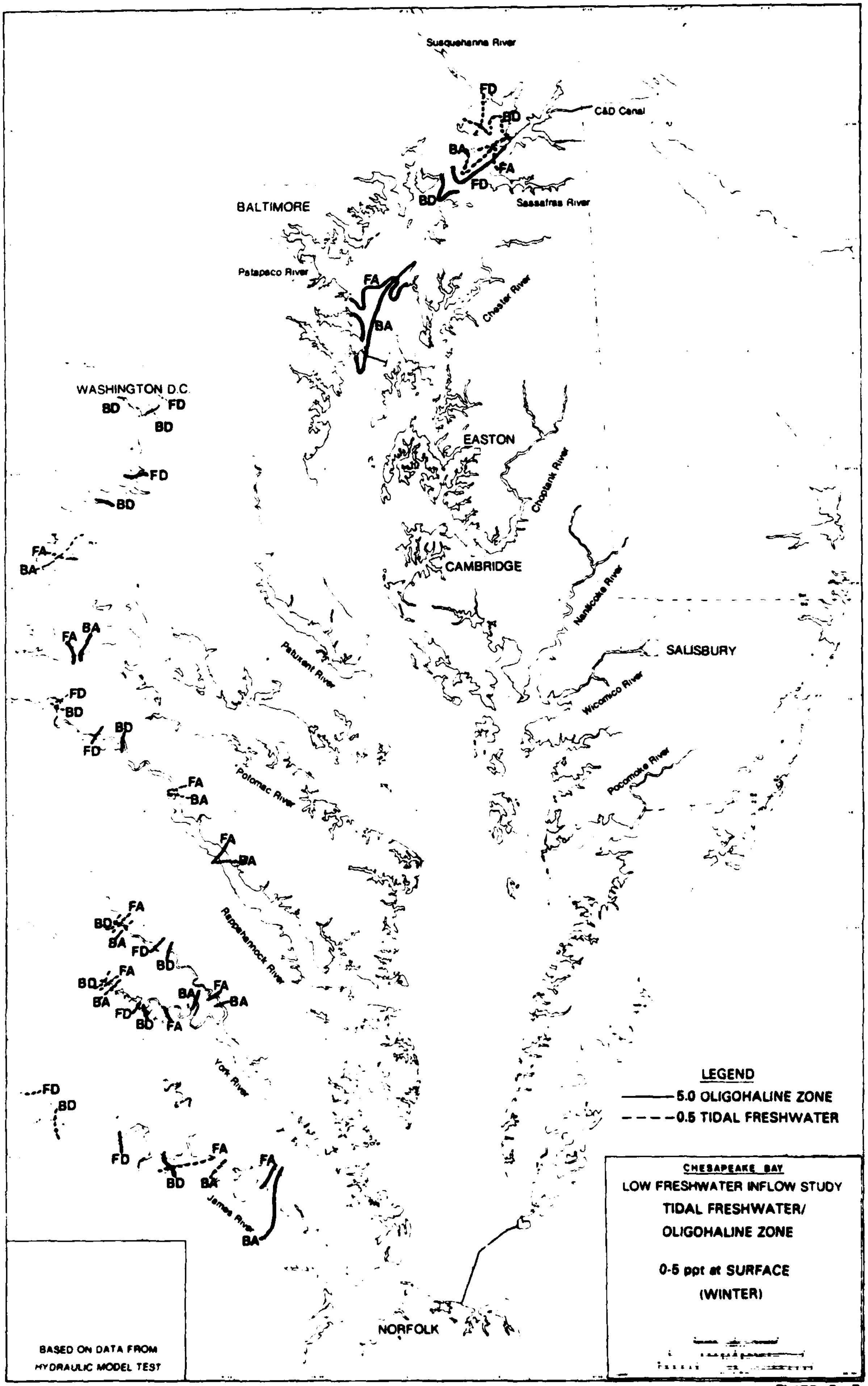
LEGEND
5.0 OLIGOHALINE ZONE
0.5 TIDAL FRESHWATER
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
TIDAL FRESHWATER/
OLIGOHALINE ZONE
0-5ppt at SURFACE
(FALL)
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE B-6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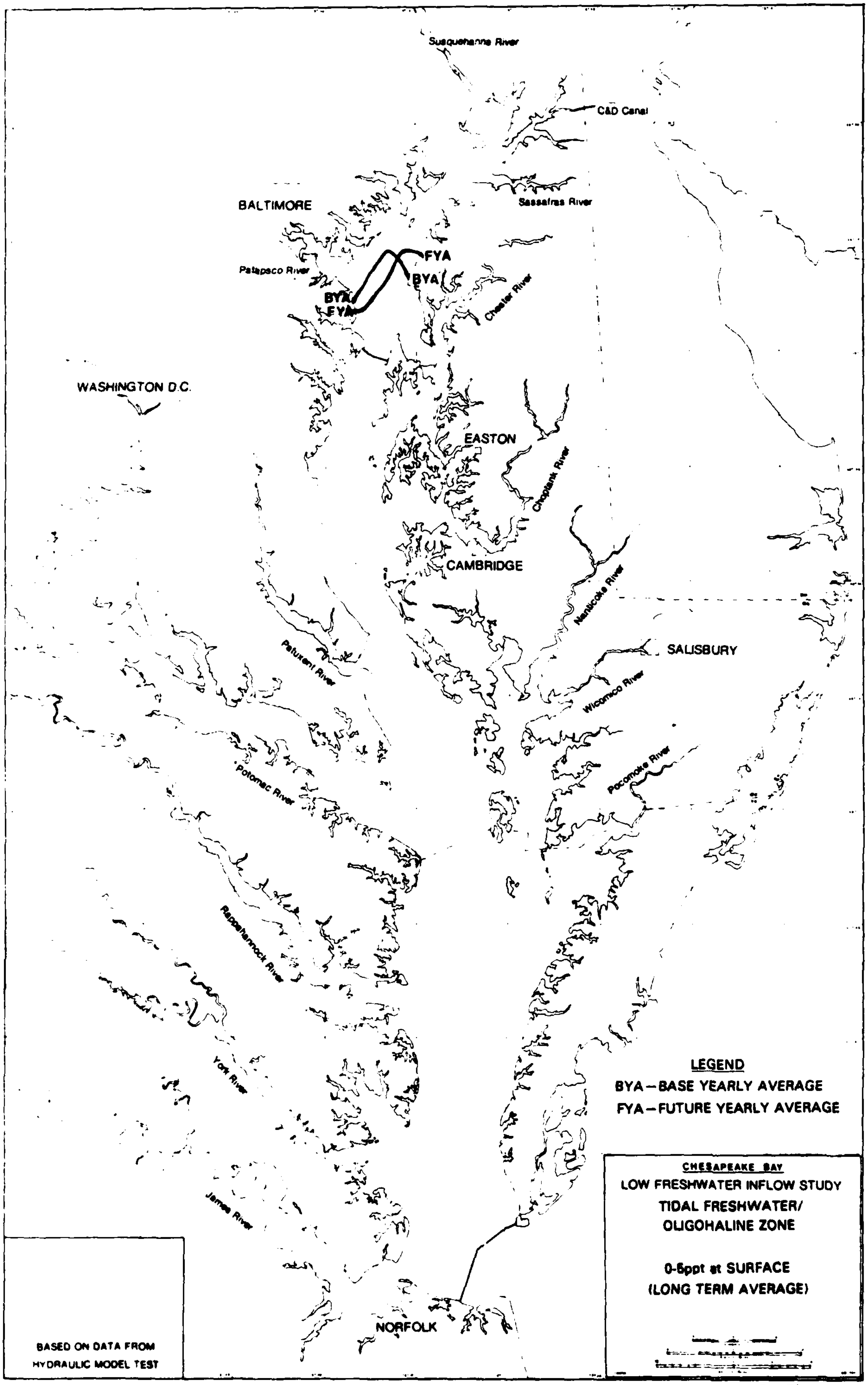
Pocomoke River
Potomac River
Rappahannock River
York River
James River
NORFOLK
FD
BD
BA
FA
LEGEND
5.0 OLIGOHALINE ZONE
0.5 TIDAL FRESHWATER
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
TIDAL FRESHWATER/
OLIGOHALINE ZONE
0-5 ppt at SURFACE
(WINTER)
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE B-7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SALISBURY
Wicomico River
Patuxent River
Potomac River
Pocomoke River
Rappahannock River
York River
James River
NORFOLK
LEGEND
BYA—BASE YEARLY AVERAGE
FYA—FUTURE YEARLY AVERAGE
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
TIDAL FRESHWATER/
OLIGOHALINE ZONE
0-5ppt at SURFACE
(LONG TERM AVERAGE)
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE B-8

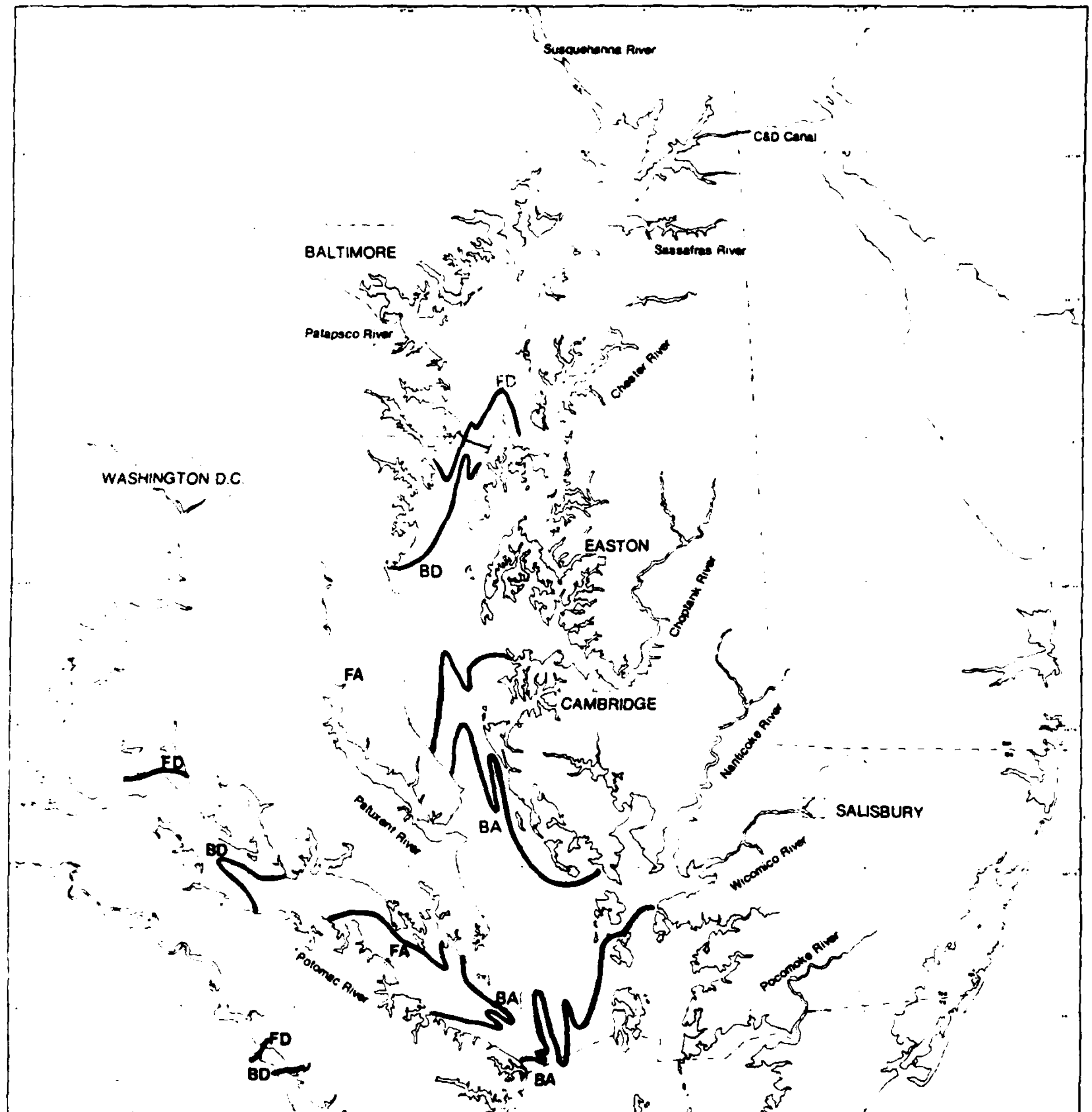

Susquehanna River
C&D Canal
BALTIMORE
Sassafras River
Patapsco River
Chester River
FD
WASHINGTON D.C.
EASTON
BD
Choptank River
FA
CAMBRIDGE
FD
Nanticoke River
Patuxent River
BA
SALISBURY
BD
Wicomico River
FA
Potomac River
Pocomoke River
BA
FD
BD
BA
FA
Rappahannock River
BA
York River
James River
NORFOLK
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
SUBMERGED AQUATIC
VEGETATION
0-12ppt at 10 feet
(SPRING)

PLATE B-9

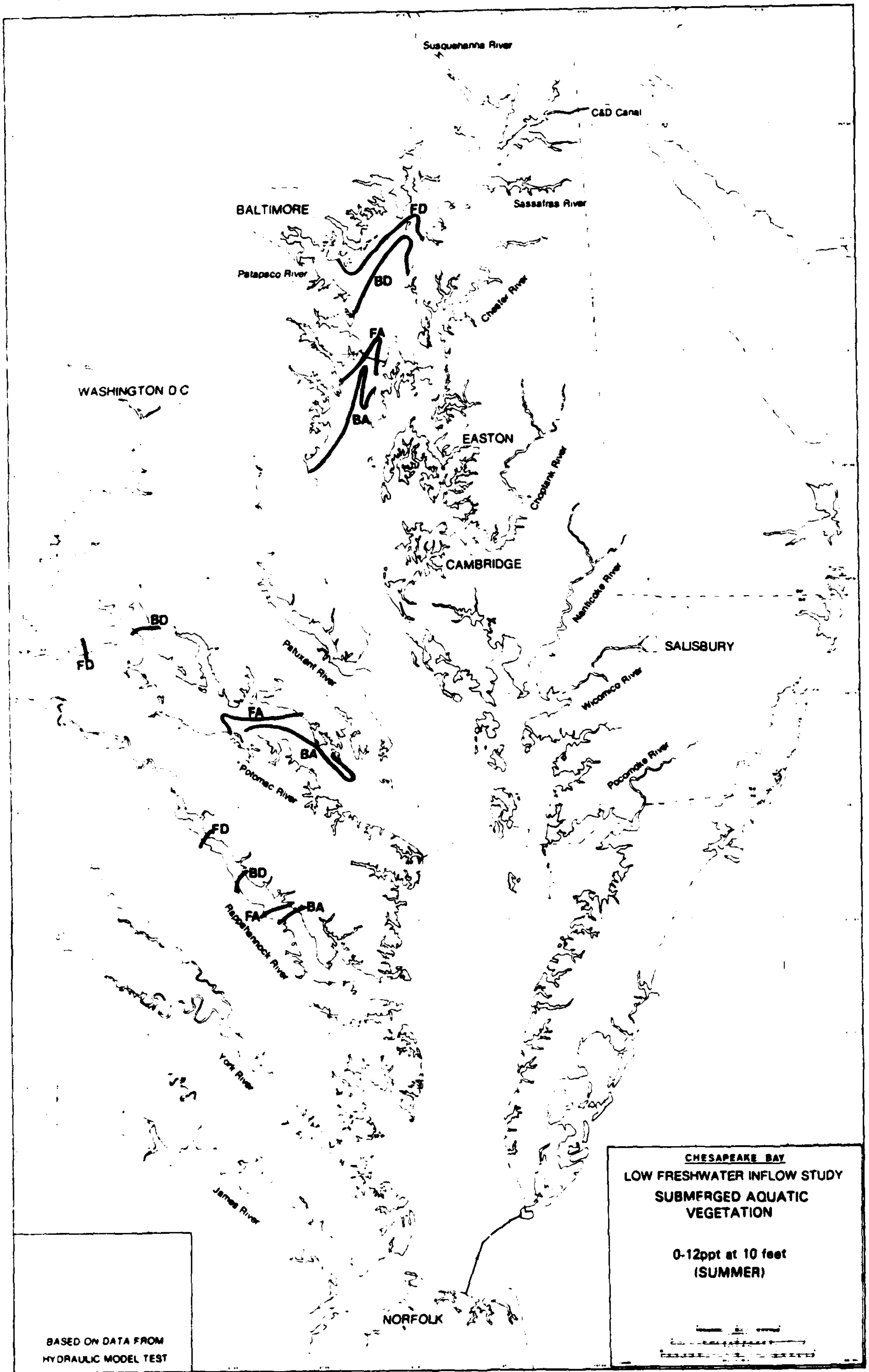

Susquehanna River
C&D Canal
Sassafras River
BALTIMORE
FD
BD
Patapsco River
Chester River
FA
BA
WASHINGTON D C
EASTON
Choptank River
CAMBRIDGE
Nanticoke River
BD
FD
SALISBURY
Patuxent River
Wicomico River
FA
BA
Pocomoke River
Potomac River
FD
BD
FA
BA
Rappahannock River
York River
James River
NORFOLK
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
SUBMERGED AQUATIC
VEGETATION
0-12ppt at 10 feet
(SUMMER)

PLATE B—10

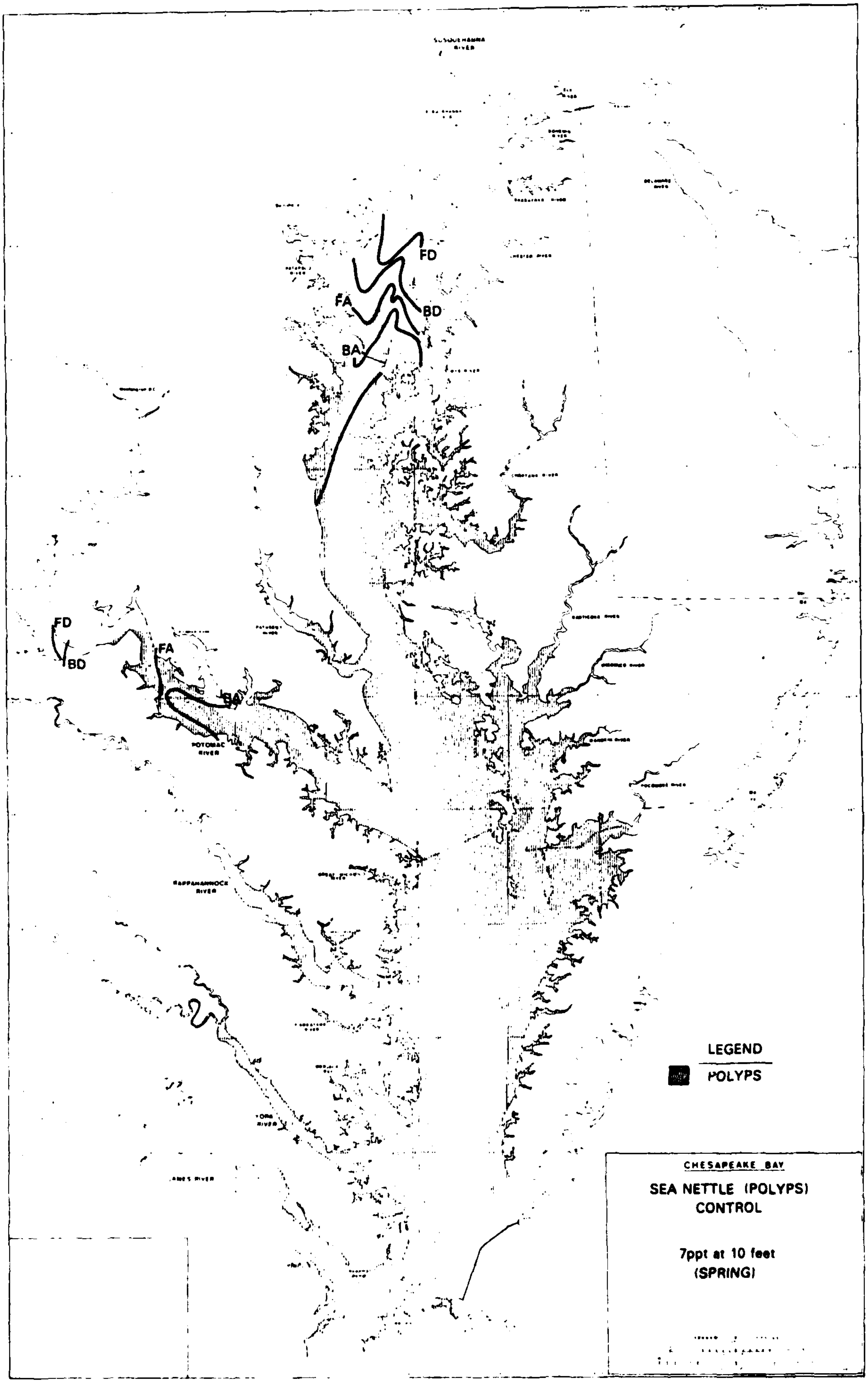
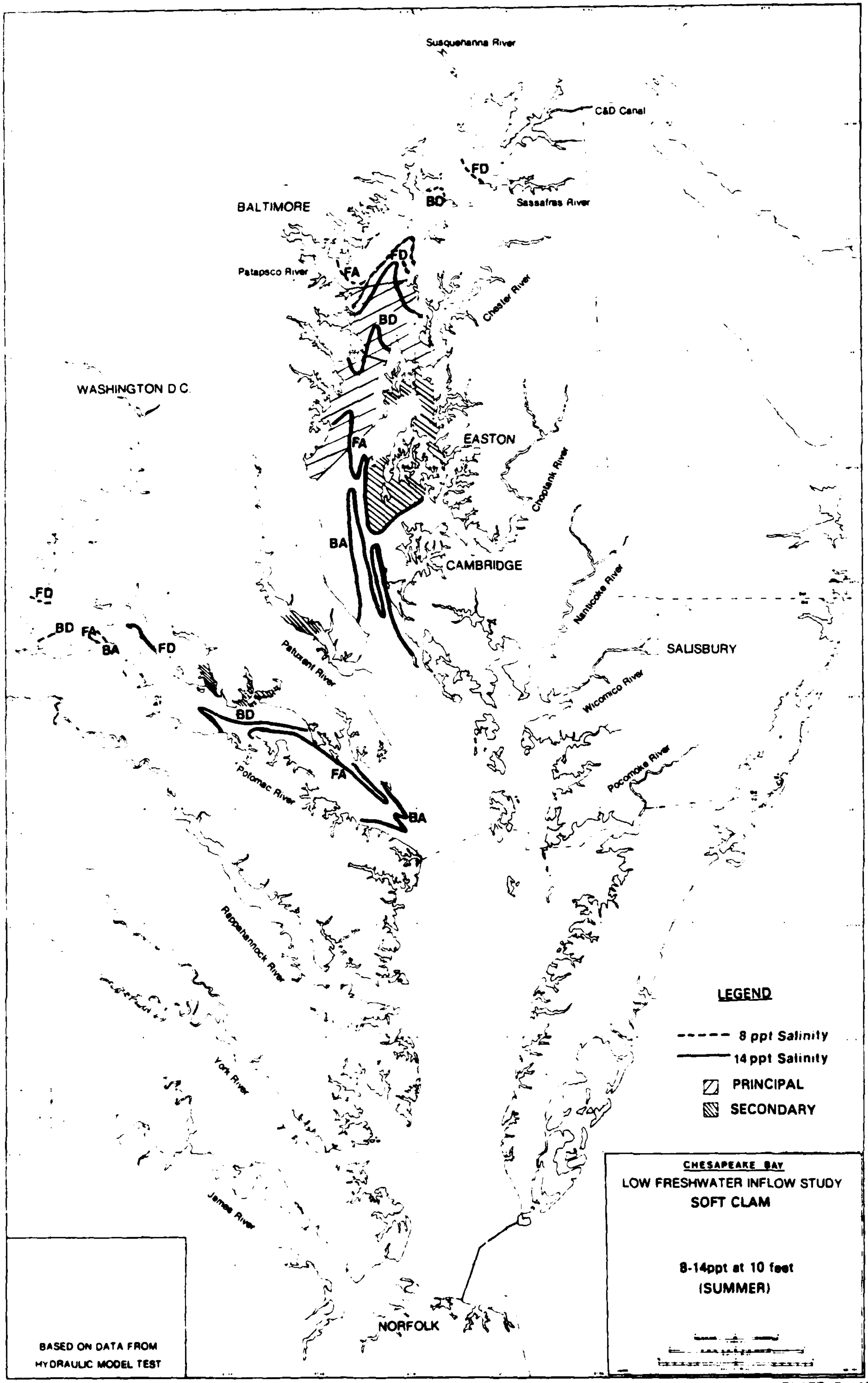

FD
FA
BD
BA
FD
BD
FA
BA
POTOMAC RIVER
RAPPAHANNOCK RIVER
LEGEND
POLYPS
CHESAPEAKE BAY
SEA NETTLE (POLYPS)
CONTROL
7ppt at 10 feet
(SPRING)

PLATE B–11


Susquehanna River
C&D Canal
FD
BD
Sassafras River
BALTIMORE
Patapsco River
FA
FD
BD
Chester River
WASHINGTON D.C.
FA
EASTON
Choptank River
BA
CAMBRIDGE
Nanticoke River
FD
BD
FA
BA
FD
Patuxent River
SALISBURY
Wicomico River
BD
FA
Potomac River
BA
Pocomoke River
Rappahannock River
York River
James River
NORFOLK
LEGEND
8 ppt Salinity
14 ppt Salinity
PRINCIPAL
SECONDARY
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
SOFT CLAM
8-14ppt at 10 feet
(SUMMER)
BASED ON DATA FROM
HYDRAULIC MODEL TEST

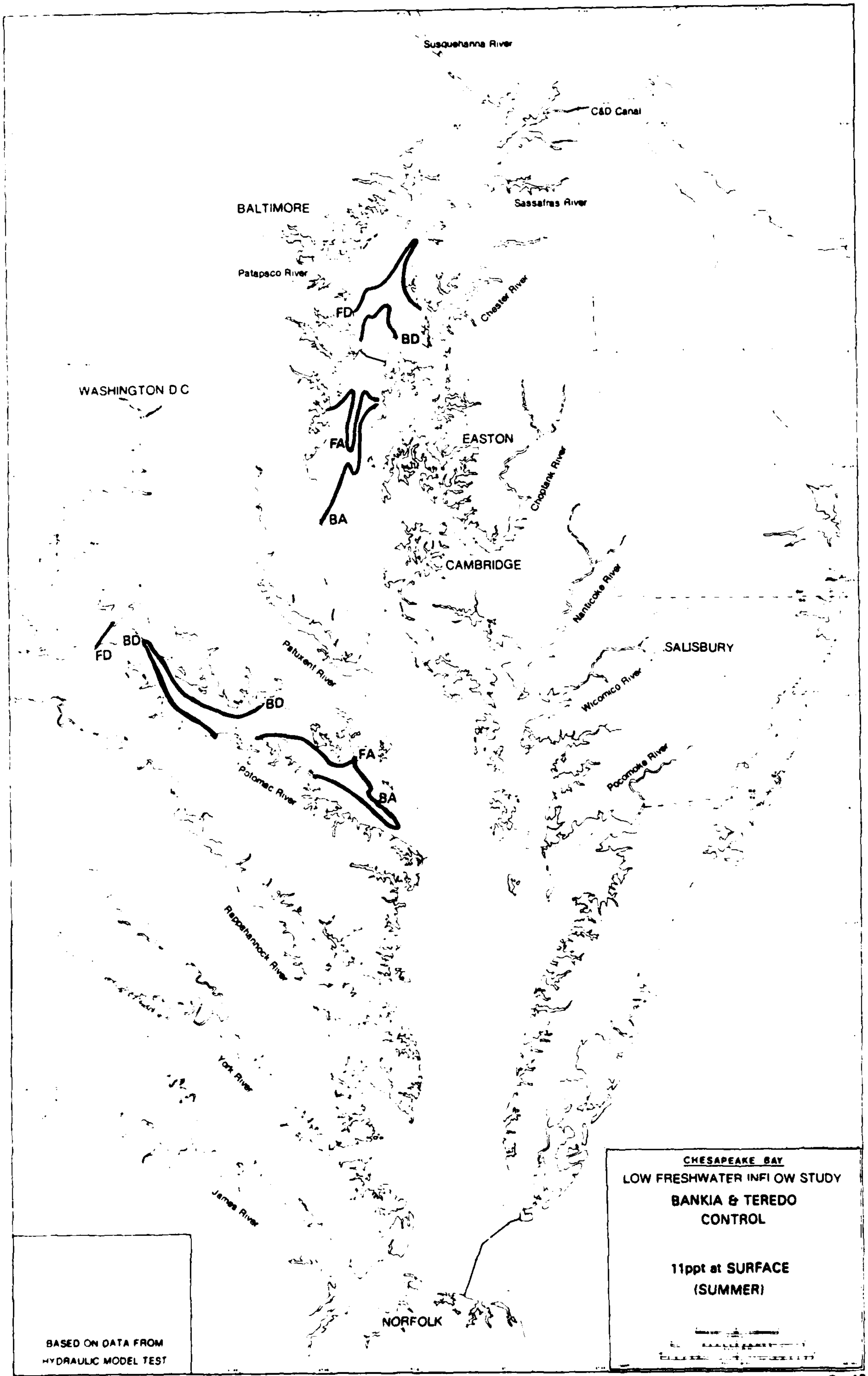

Susquehanna River
C&D Canal
Sassafras River
BALTIMORE
Patapsco River
Chester River
FD
BD
WASHINGTON D C
FA
EASTON
Choptank River
BA
CAMBRIDGE
Nanticoke River
BD
FD
SALISBURY
Patuxent River
Wicomico River
BD
FA
Pocomoke River
Potomac River
BA
Rappahannock River
York River
James River
NORFOLK
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
BANKIA & TEREDO
CONTROL
11ppt at SURFACE
(SUMMER)

PLATE B—13

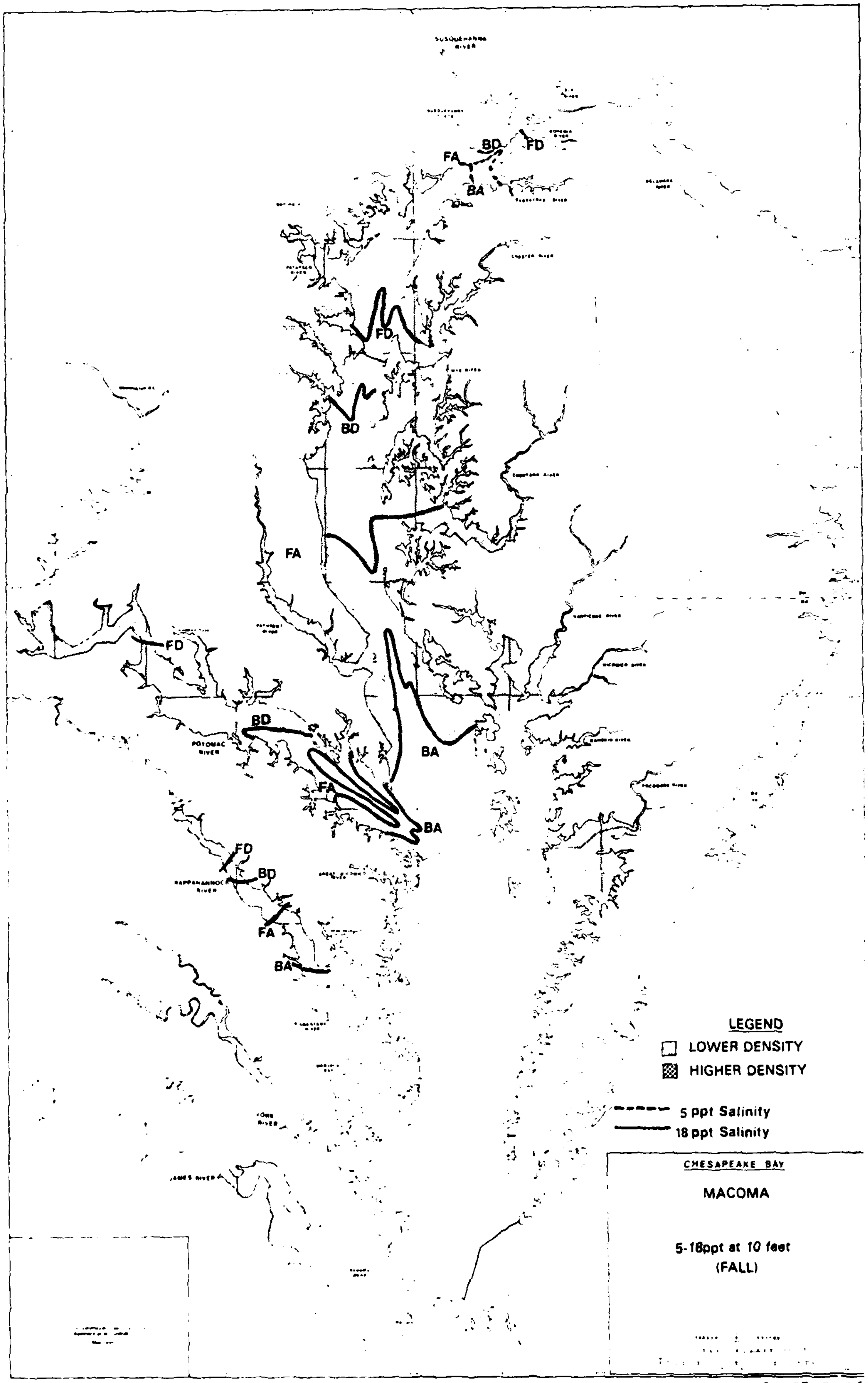

FA
BD
FD
BA
FD
BD
FA
BA
FD
BD
FA
BA
FD
BD
FA
BA
POTOMAC RIVER
LEGEND
LOWER DENSITY
HIGHER DENSITY
5 ppt Salinity
18 ppt Salinity
CHESAPEAKE BAY
MACOMA
5-18ppt at 10 feet
(FALL)

PLATE B-14

CHESAPEAKE BAY

LOW FRESHWATER INFLOW STUDY

APPENDIX C

HYDROLOGY

Department of the Army
Baltimore District Corps of Engineers
Baltimore, Maryland
September 1984

CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY

APPENDIX C

HYDROLOGY

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CHAPTER I

CHARACTERISTICS OF CHESAPEAKE BAY

INTRODUCTION

Chesapeake Bay, together with its tributary arms, forms a huge and complex estuarine system. In this system, both circulation patterns and longitudinal salinity distribution are affected by variations in freshwater inflow. The purpose of this appendix is to describe briefly certain characteristics of the Chesapeake Bay system and, as well, derive freshwater inflows and consumptive losses to be expected in the future. Of particular interest is the magnitude of freshwater inflows during periods of drought.

Chapters I and II introduce basic concepts of estuarine circulation and salinity patterns as related to Chesapeake Bay and describe geological aspects of the large drainage basins tributary to the Bay. Chapters III, IV, and V supply hydrologic and consumptive loss data and derive the future expected freshwater inflows that were simulated on the Chesapeake Bay Model.

PHYSICAL PROCESSES

Pritchard's classic definition of an estuary is "a semi-enclosed body of water that has a free connection with the open sea and within which seawater is measurably diluted with freshwater from land drainage." The mixing of freshwater and saltwater under the influence of astronomical tides, wind, rain, and other physical forces creates a unique dynamic estuarine environment that characterizes Chesapeake Bay and its tributary waters.

The longitudinal axis of Chesapeake Bay is oriented in the north-south direction, parallel to the Atlantic Coast. The tidal shoreline is an estimated 7,300 miles in length — 2,900 miles of shoreline in Virginia, 4,400 miles in Maryland. Approximately 200 miles long, it varies in width from 4 miles near the William Preston Lane Memorial Bridge to about 30 miles wide near the mouth of the Potomac River. The surface area of Chesapeake Bay and its tributary estuarine waters is approximately 4,300 square miles. While Chesapeake Bay itself has a mean depth of approximately 28 feet, the entire estuarine system, including tributaries to the head of tide, averages about 25 feet in depth. The deepest point in Chesapeake Bay, a hole near Bloody Point at the southern end of Kent Island, is about 174 feet deep.

Chesapeake Bay, shown on Figure C-I-1, lies entirely within the Atlantic Coastal Plain. The melting and retreat of the glaciers at the end of the Wisconsin period of glaciation caused a rise in sea level from a position some 375 feet below its present level. The level of the sea rose, crossed the continental shelf, and drowned the mouth of the ancestrial Susquehanna River, reaching the mouth of the Chespeake Bay less than 10,000 years ago. With the continuing rise in sea level, seawater advanced further into the basin, changing it from a riverine into an estuarine system. The age of the estuary decreases from its mouth at the Atlantic Ocean towards the head of tide; some geologists estimate that the northern portion of Chesapeake Bay is less than 10,000 year old.

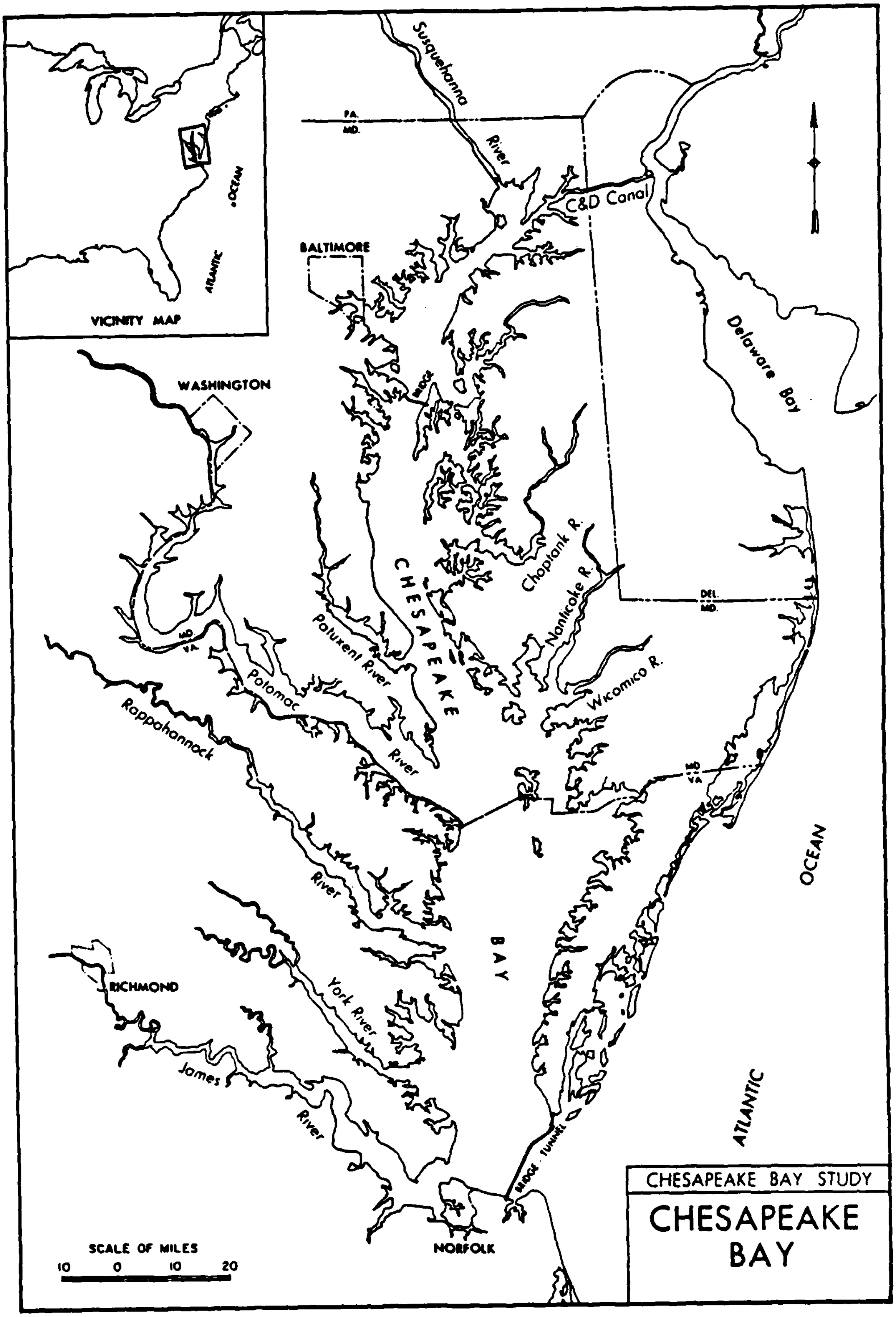


FIGURE C-I-1 CHESAPEAKE BAY

Tides

The pulse of Chesapeake Bay, the rise and fall of its water surface with the flood and ebb of the tide, is the most easily distinguished mass movement of water in the estuary. The mean tidal fluctuation in Chesapeake Bay is small, generally between one and two feet. Average maximum tidal velocities range from 0.5 knots to over 2.0 knots. Tidal currents, being oscillatory in nature, do not function as a mechanism for the net transport of water, or suspended and dissolved materials.

Circulation Patterns & Salinity

Tidal currents generally flow along the longitudinal axis of the estuary. In broader sections of the water body; however, cross-stream flows may develop. Other flows, however, are masked by the tidal currents. Within Chesapeake Bay and its major tributaries, there is (superimposed on the tidal currents) a non-tidal, two-layered circulation pattern. This flow pattern provides a net seaward flow in the upper layer of the water column, as well as a flow along the bottom of the estuary directed landward. Freshwater inflow from tributary basins generates these complex non-tidal circulation patterns.

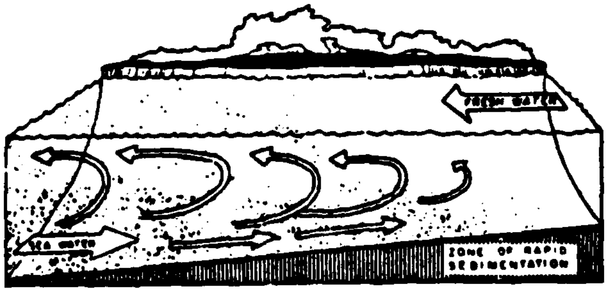
Figure C-I-2 illustrates the two-layer circulation pattern typical of partially mixed coastal plain estuarines such as the Chesapeake. It will be noted that dense saltwater enters the estuary from the ocean flowing under a less dense layer of riverine water flowing toward the sea at the surface. Tidal forces, as well as wind and internal friction, interacts to produce mixing between the surface layer and the more dense bottom water.

This basic two-layered circulation pattern, characteristic of coastal plain estuaries, is found also in the major tributary arms of Chesapeake Bay, including the Potomac and James River estuaries.

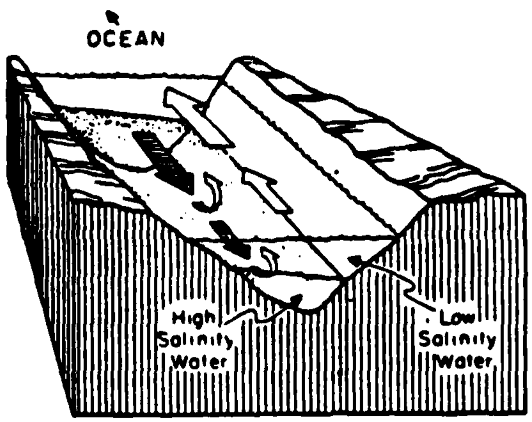
Because of riverine inflow and the net non-tidal density driven circulation pattern, the volume rate of seaward directed flow in the upper layer discharging into the Atlantic Ocean has been estimated to be approximately 10 times the riverine inflow. In turn, the rate of inflow of seawater up the bottom of Chesapeake Bay is estimated to be nine times the freshwater inflow into the system.

The seasonal distribution of salinity in Chesapeake Bay and its tributary estuaries is determined primarily by freshwater flow into the system. The mixing of freshwater and seawater is produced by forces exerted by the tides and wind action. Within the Bay, salinity varies from that of the ocean at its mouth (31-33 parts per thousand) to that of freshwater flowing into the Bay (0.1 part per thousand near the mouth of Susquehanna River). Marked seasonal variations in freshwater inflow produce seasonal variations in salinity. The variations are most marked in the upper Bay and its tributaries. Near Pooles Island in the upper Chesapeake Bay, salinity during 1960, a year of relatively high Susquehanna River inflow, ranged from 0.4 ppt in April to 8.0 ppt in December — a more than 20-fold range. The variation in salinity is one of the significant physical forces influencing estuaring circulation dynamics in Chesapeake Bay.

The transition from river to estuary at the head of Chesapeake Bay is distinguished by a pronounced salt "front" separating "fresh" Susquehanna River water from the saltier water of the estuary. The salt front moves both upstream and downstream in response to



A. Side view



B. View looking seaward in northern hemisphere

Source: Schubel and Pritchard, 1972

FIGURE C-I-2 VIEWS OF A PARTIALLY MIXED ESTUARY

decreasing and increasing Susquehanna River inflows. Upstream of the salt "front," the flow of the entire water column is seaward while downstream the two-layered circulation pattern exists. Proceeding downstream, the salinity of both the top and bottom layers of the water column increases with the lower layer being the more saline.

Seasonal differences in both salinity distribution and circulation patterns reflect seasonal changes in river runoff and seasonal changes in temperature. Increased runoff in early spring increases the degree of strength of density stratification of the water column and increases the volume of saltwater flowing up the bottom of the estuary and in turn decreases the degree of mixing between the upper and lower layers. Conversely, density stratification is weakest during the winter's extensive periods of low freshwater inflow.

Circulation in Small Sub-estuaries. The circulation of small sub-estuaries (Gunpowder, Bush, Back, Magothy, Severn) do not follow the classic two-layered pattern exhibited in Chesapeake Bay and the larger tributaries such as the Potomac and James Rivers. The smaller tributaries have small drainage areas and, consequently, a relatively small volume of freshwater inflow. The water in these small sub-estuaries is primarily of Chesapeake Bay origin. Salinity variations in the upper layers of Chesapeake Bay, over time, are the major factors driving the exchange of water between the Bay and these smaller water bodies. Salinity values of the upper layers of the Bay vary seasonally, with maximum values in the fall or winter, and minimum values in the spring. Changes in salinity in the tributaries lag behind those in the adjacent Bay. During winter and early spring, water tends to flow from the Bay into the tributaries at the surface, and out of the tributaries from their deeper levels into the Bay. In the late spring, summer, and early fall, when the salinity of the Bay is increasing, the salinity in the tributaries tends to be less than in the adjacent Bay. Water from the tributaries flow out at the surface, while more dense water from the Bay flows in along the bottom. The circulation pattern of these estuaries changes twice each year, effectively flushing out the minor tributaries twice a year. The small Western Shore tributaries of the Upper Bay (Gunpowder and Bush) are subject to sharp changes in the rate of exchange of water between them and the Bay, resulting from short-term, rapidly fluctuating salinity of the adjacent surface waters of the Bay produced by large changes in the discharge of the Susquehanna River. Also, recent investigation suggests that wind stress can also play an important role in the circulation of these small water bodies.

Baltimore Harbor. The circulation of Baltimore Harbor, often referred to as the Patapsco River Estuary, is driven primarily by differences in water density between the Patapsco River and the adjacent Chesapeake Bay. The circulation pattern of Baltimore Harbor is characterized by a three-layer flow pattern that includes a flow into the harbor at both the surface and along the bottom, and a return flow to the Bay at mid-depth. The dredged navigation channel, that is essentially the same depth as the adjacent Bay, plays a most important part in establishing the three-layer system in that without the channel, circulation within Baltimore Harbor would resemble that of the Gunpowder and Bush Rivers.

In summary, Chesapeake Bay and its tributary arms constitute a very complex estuarine system. Freshwater inflows from major tributary rivers establish the classic two-layer estuarine circulation pattern characterized by an upstream flow of more dense salty water along the bottom layer and an upper layer of brackish water flowing seaward. Marked variations in freshwater inflow produce variations in salinity in the main Bay, these establish the mechanisms for flushing smaller Upper Bay tributary arms that lack sufficient freshwater inflow.

Sediments and Turbidity

Sediments are introduced into the Chesapeake Bay by the rivers, by shore erosion, by biological activity, and by the sea. Most of these sediment inputs are poorly quantified. The sediment discharged by the rivers is fine-grained silt and clay, most of which is trapped and deposited in the upper reaches of the estuaries. Shore erosion is probably the most important source of sediment in the middle and lower portions of the Bay. Biological processes also play an important role in the sedimentation process.

Suspended sediments limit the depth to which light sufficiently intense to support photosynthesis can penetrate into the water column. This, is turn, limits the production of uni-cellular plants, important for food. Also, because of their high sorptive capacity, clay particles concentrate heavy metals, nutrients, oil, pesticides, biocides, and other contaminants. Since these pollutants are "attached" to fine particles, they are concentrated and deposited in the upper reaches of the Bay and its tributaries. These indirect effects of sediments are probably of greater significance to man than the long-term direct effects of filling, and, in turn, are not completely understood.

The turbidity maxima found in both Chesapeake Bay and its major tributary arms, is made up of fine-grained, suspended sediment trapped by the net non-tidal circulation patterns. The position of turbidity maxima is determined by the location of the salt front. It lies in the transition zone, between fresh and salty portions of the estuary. It is here that net upstream flow of the lower layer in the estuary dissipates until the net flow is downstream at all depths. Further, turbidity maxima are characterized by suspended sediment concentrations and turbidity values that are higher than those either further upstream or downstream.

Within the Chesapeake Bay, most sedimentary material, both newly introduced through the Susquehanna River and that resuspended by wind and tidal currents, is trapped in the upper 30-40 km. of the northern part of the estuary by the net non-tidal estuarine circulation. Near the head of the estuary, an effective trap for sediments, nutrients, and planktonic organisms is formed where the net upstream flow of the lower layer dissipates. The net-flow is downstream at all depths. Suspended sediment particles that settle out of the upper seaward flowing layer into the lower layer are transported back upstream by the net non-tidal upstream flow. Further, many of these suspended particles are transported back into the upper layer by the forces of vertical mixing. The whole process is repeated many times.

The Importance of Freshwater Inflow

It is well known that the mixture of freshwater inflow from rivers and streams tributary to the Chesapeake Bay estuarine system and the saltwater from the ocean are the primary factors defining the physical and biological characteristics of the estuary.

The freshwater inflow delivers nutrient material, sediments, and trace metals of terrestrial origin that are necessary to establish estuarine living conditions. Further, the net non-tidal circulation patterns characteristic of the system tend to not only concentrate nutrients and sediments within the estuary, but also to distribute them within the system.

The mixture of freshwater and saltwater eventually defines the combination of temperatures, salinity, and food that is "just right" for a large number of organisms. It is a unique home where organisms can select environmental conditions not competing with other estuarine organisms. Also different salinity regimes within the estuary provide localities suitable for reproduction.

The circulation patterns developed in the estuarine system are important. The movement of water transports plankton, eggs of fish, shellfish, larvae, sediments, minerals, nutrients, organic detritus, and other chemicals. The two-layer net non-tidal circulation in Chesapeake Bay has a great effect on spawning activity. Many migratory fish species, including shad and herring, travel from the ocean to spawn in the freshwater areas of the upper Chesapeake Bay and its major tributary arms. Other migratory fish species, including croaker, menhaden, drum, and spot, spawn in the ocean. Their larvae then enter Chesapeake Bay and drift upstream with the flow of bottom waters to nursery grounds in the upper Bay.

CHAPTER II

BASIN DECRIPTION

GENERAL DESCRIPTION

As stated in Chapter I of this appendix, it is the mixture of freshwater inflows from the rivers and streams tributary to Chesapeake Bay and saltwater from the ocean that are primary factors defining the physical characteristics of the estuary. In turn, it must be stressed that the seasonal distribution of freshwater inflow is a most potent biological force. It became most important for the purposes of the Low Freshwater Inflow Study to develop a large amount of hydrological data for simulating freshwater inflows on the hydraulic model.

The 64,160 square mile Chesapeake Bay Drainage Basin is shown on Figure C-II-1. It extends from Southern New York to Northern Virginia and includes portions of the States of New York, Pennsylvania, Maryland, Virginia, West Virginia and Delaware. There are over 50 tributary rivers with widely varying geo-chemical and hydrologic characteristics contributing freshwater to Chesapeake Bay. The largest river on the East Coast of the United States, the Susquehanna, drains nearly 43 percent of the basin and contributes 51 percent of the inflow while the York, Rappahannock and James system drains nearly 25 percent of the basin and contributes about 21 percent of the freshwater inflow. The Potomac, draining 22 percent of the basin provides 18 percent of the total inflow. The Patuxent is the smallest of the major rivers draining only a little over one percent of the basin and contributing only 1.5 percent of the freshwater inflow.

TABLE C-II-1

BASIN CHARACTERISTICS

Sub Basin	Drainage Area ($mi.^2$)	Percent Total Basin	Average Freshwater Inflow (cfs)	Percent Total Inflow
Susquehanna	27,510	43	39,240	51
Potomac	14,217	22	13,770	18
Rappahannock	2,885	5	2,940	4
York	2,857	4	2,660	3
James	10,187	16	10,940	14
Patuxent	875	1.5	884	1.5
Eastern Shore	4,061	6	4,697	6
Upper Western Shore	1,568	2.5	1,758	2.5

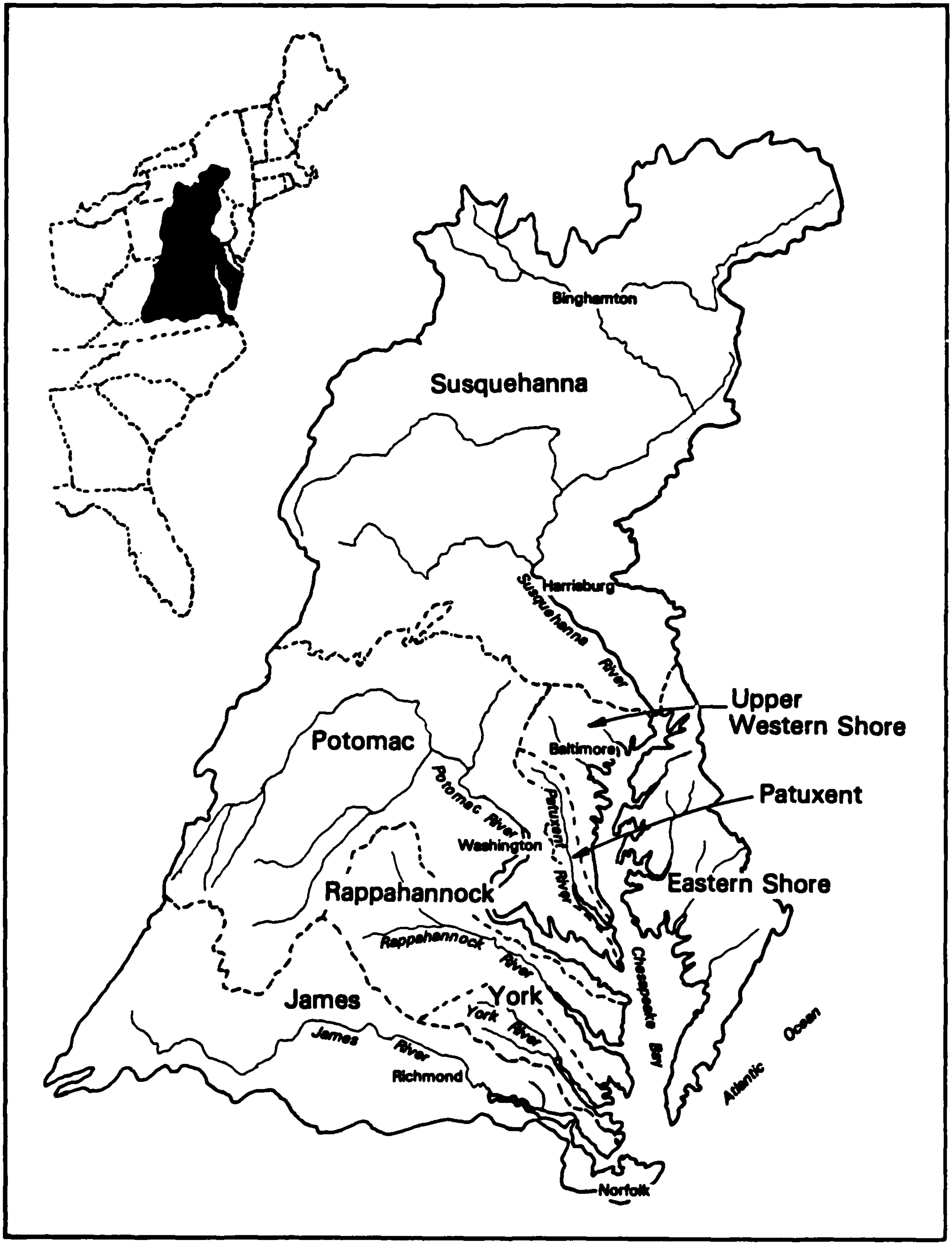


FIGURE C-II-1 CHESAPEAKE BAY DRAINAGE BASIN

The Upper Western Shore and Eastern Shore Basins are composed of many streams and rivers; all of which have small discharges of freshwater. The larger rivers on the Upper Western Shore include the Severn, Magothy, Patapsco, Middle, Back, Gunpowder and Bush Rivers. The flat, low discharge streams of the Eastern Shore include the Chester, Wye, Tred Avon, Choptank, Nanticoke and Pocomoke Rivers.

GEOLOGY

The Chesapeake Bay Drainage Basin is made up of 5 physiographic provinces. These are the Coastal Plain, Piedmont Plateau, Blue Ridge Province, Valley and Ridge Province and the Appalachian Plateau. All of these provinces parallel the Atlantic Coast in belts of varying width that extend from New England to the Gulf of Mexico. Their locations are shown on Figure C-II-2.

Atlantic Coastal Plain Province

The Coastal Plain appears as a low, partially submerged surface, bounded by the Piedmont Plateau on the west and the edge of the Continental Shelf on the east. The Coastal Plain and Piedmont are separated by a boundary known as the Fall Line which is marked by the feathering out of softer sedimentary formations of the Coastal Plain as they come into contact with the harder crystalline rocks of the Piedmont. The Fall Line marked the head of navigation on tributaries when the Bay area was settled by the colonists. This feature, plus the fact that water power was greatest at the Fall Line (due to the falling of water from the Piedmont Plateau onto the Coastal Plain), resulted in settlements springing up along the East Coast where the Piedmont joins the Coastal Plain. These settlements later developed into major urban centers.

The eastern boundary of the Coastal Plain is the edge of the Continental Shelf which lies about 100 miles offshore at a depth of 600 feet. The Coastal Plain is divided diagonally by Chesapeake Bay into the Eastern and Western Shores. The former is flat, low, almost featureless, and the latter is a rolling upland. The higher elevation of the Western Shore has permitted rivers such as the Susquehanna, Patapsco, Patuxent, Potomac, Rappahannock, York, and James to carve, generally, deeper channels than those rivers of the Eastern Shore which include the Chester, Choptank, Nanticoke, and Wicomico. This has created a condition of greater comparable relief on the Western Shore than that found on the Eastern.

The coastal shoreline, which separates the submerged portion of the Coastal Plain from the subaerial portion, is extremely broken, low, and marshy in places. Where the shore is straight, the coast tends to be high bluffs. Along most of the shore lies a series of sandy barrier beaches.

Large areas of the Coastal Plain lie submerged beneath the waters of the Atlantic. Off Maryland, the submerged area is approximately 5,000 square miles. In Virginia, the Coastal Plain consists of a total of 14,000 square miles of which 10,000 of these are subaerial; the remainder are submarine.

Broad tidal estuaries, particularly in Virginia, penetrate to the Fall Line and divide the Coastal Plain into a series of long, narrow peninsulas. Many areas in and near these estuaries have existed as large swamp areas.

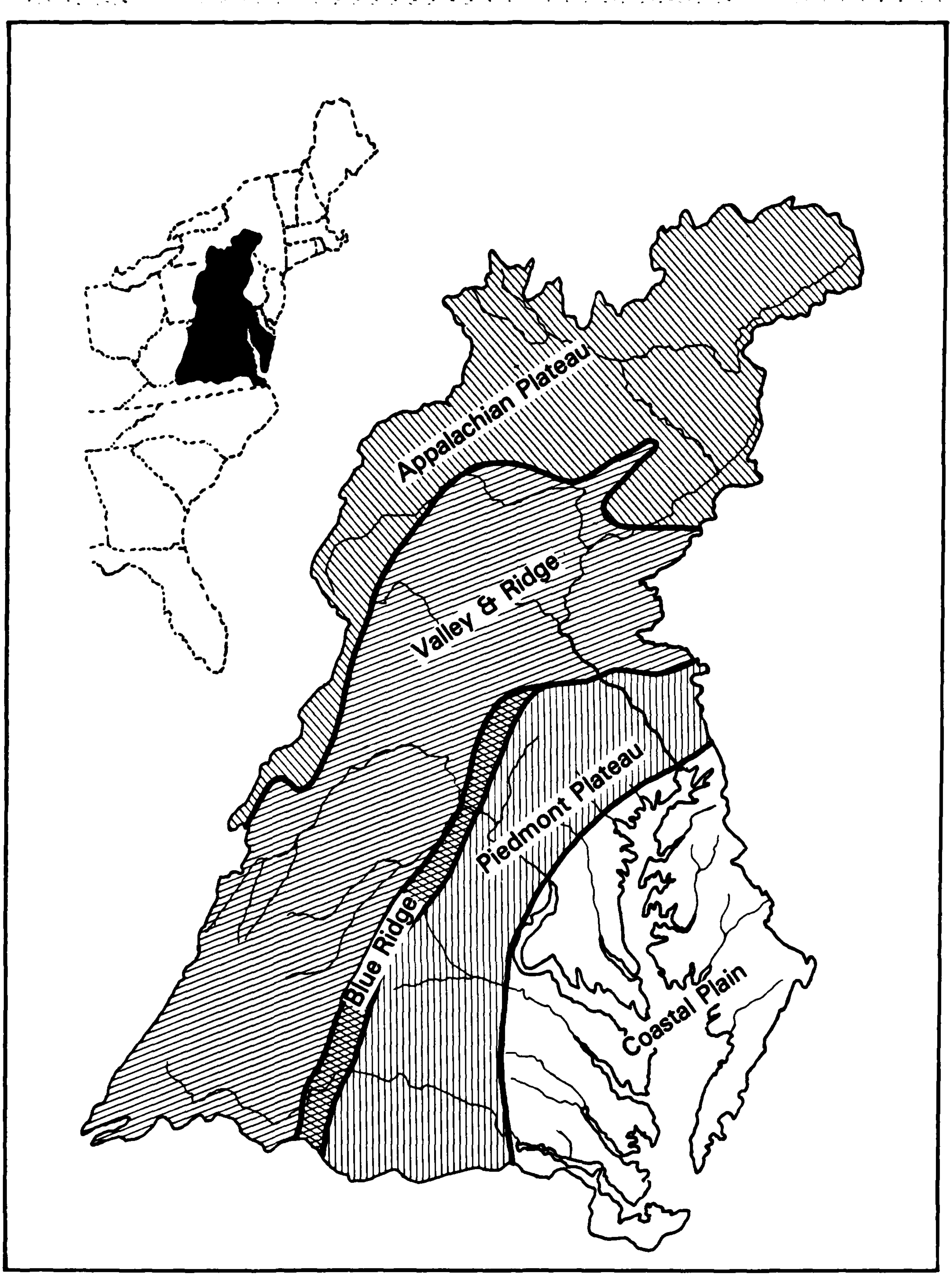


FIGURE C-II-2 GEOLOGIC PROVINCES

The Coastal Plain ranges in altitude from sea level to about 300 feet. Probably the most striking physiographic feature, according to some sources, is the presence of the great and intricate dendritic system of navigable waterways. Narrow terrace plains extend up the valleys of the larger estuaries and waterways to the Fall Line. The younger terrace plains are believed to be emerged marine deposits laid down during the Pleistocene epoch (Ice Age). Hilly tracts within the Bay region are older, higher terraces which have been dissected by stream erosion and are of either marine origin (deposited by the sea) or fluvial origin (created by streams).

Piedmont Province

The Piedmont Plateau is a broad, undulating surface with low knobs and ridges rising above the general lay of the land. Numerous deep and narrow stream valleys dissect the province. Low hills gradually rise from the Fall Line (its eastern boundary) to the Appalachian Province on the west.

The Piedmont Plateau has a gentle southeastward slope which begins approximately 1,000 feet above sea level in the west and slopes downward to about 200 feet above sea level in the east. From here, the Piedmont rocks pass beneath the Coastal Plain sediments.

Streams that originate in the Piedmont cut narrow steep-sided valleys in the hard crystalline base rocks and produce falls and rapids. These same water bodies cut wide and open valleys in the loose sediments of the Coastal Plain.

The Piedmont Province is divided into two divisions: the Eastern and Western. The eastern section is highly diversified due to the variety of rock types (each of which vary according to their resistance to erosion) and the complications in structural relationships of the rocks.

Most of these are complex, metamorphosed series including gneisses, slates, phyllites, schists, marble, serpentine, granite, and gabbro. Streams in this division are unnavigable, rapid, and have steep gradients and small waterfalls.

In the western division of the Piedmont, the rocks are again of metamorphic type, only much less metamorphosed than those of the eastern division.

Valley and Ridge

The Valley and Ridge Province is a region of alternating hard and soft sedimentary rocks that have been bent by enormous lateral compression into folds or waves technically known as "anticlines" and "synclines." At the end of Paleozoic time, the strata of the Valley and Ridge Province were subjected to strong pressure from the southeast and folded into these great anticlines and synclines, and in places over-turned toward the northwest. Faults were also commonly developed in the zone of greatest pressure, while farther west, the horizontal attitude of the beds were scarcely disturbed. This folding has produced the high ridges and valleys of moderate width that are its distinctive feature. The ridges generally run northeast-southwest with a slight pitch to the southwest and sweep off at the north in broad curves to a more easterly direction. These ridges and valleys have influenced the creation of the general trellis-shaped drainage pattern present in the Valley and Ridge.

The Valley and Ridge Province is underlain by a sequence of alternating conglomerate, sandstone, shale, limestone, and coal. The conglomerates and sandstones are the "ridge-makers" and the less resistant limestones and shales underlie the valleys of the region. The resistance of the rocks to erosion varies greatly and has a very important effect upon the topography. The broad lowlands composing the Great Valley are due to the weakness of the Cambro-Ordovician limestones and Ordovician shales. The ridges of the Valley and Ridge belt are composed of very resistant Middle and Upper Paleozoic sandstones and conglomerates, particularly the Tuscarora Sandstone (Silurian), Oriskany Group (Devonian), Pocono Formation (Mississippian), and Pottsville Formation (Pennsylvania). Ordovician, Silurian, and Devonian Shales and limestones underlie the valleys.

The northeastern part of the Valley and Ridge has been glaciated and exhibits glacial deposits. In the eastern part of the region are belts of folded shale, sandstone, conglomerate, and anthracite coal of Mississippian and Pennsylvanian age that produce the distinctive anthracite coal fields of Pennsylvania. The Broad Top Coal Field is similar, but has been less severely deformed and contains bituminous coal. The Great Valley south of Blue Mountain is underlain by shale in its northern part and by limestone and dolomite in its southern part.

The ridges of the mountainous area rise to an elevation of more than 2,200 feet with a relief from 500 to 1,600 feet above the surrounding valleys. The southward pitch of the folds has produced a peculiar series of canoe-shaped valleys. Where the synclinal (downwarped) folds are eroded, the mountains surrounding the valleys gradually converge to form what would represent the prow. Where anticlinal (upwarped) folds are truncated, a series of cigar-shaped mountains result. This peculiar system of ridges surrounding "blind" valleys has had a decided influence upon the region. Travel across it has been difficult, retarding development and increasing the expense of railroad construction. Its influence upon the drainage system as a whole has been marked, and the original drainage systems have suffered many radical changes.

The major lowland in the Valley and Ridge Province is the Great Valley that stands at an elevation of between 400 and 800 feet. This area has wide depressions exhibiting true valley characteristics, rather than being enclosed by level-crested parallel ridges.

Blue Ridge Province

The Blue Ridge Province consists of a narrow band of mountains between the Piedmont and the Valley and Ridge Provinces. These mountains extend from southern Pennsylvania to northern Georgia. One of the most prominent of them is South Mountain in Pennsylvania. Marked topographic breaks separate it from the Great Valley section of the Valley and Ridge Province on the northwest and the much lower Piedmont Province on the southeast. The Blue Ridge rises to an elevation of 2,000 feet in South Mountain which consists of a core of Precambrian rhyolite, basalt, and volcanic rocks. The igneous rocks are overlain unconformably by sedimentary rocks, chiefly sandstones and shales of Cambrian age which have been altered, in part, to quartizite and phyllite.

Appalachian Plateau

The Appalachian Plateau forms the western division of the Appalachian Highlands. The Plateau may be traced eastward to the Catskill region and southward to Alabama. Its

eastward face is usually recognizable in a pronounced erosional escarpment called the Allegheny Front, whereas westward it merges gradually into the Great Plains of the Mississippi Valley.

Geologically, the Plateau is underlain by sedimentary rocks deposited during the Paleozoic Era including conglomerates, sandstones, shales, limestones, and bituminous coal of Devonian, Mississippian, and Pennsylvanian age. The rocks are nearly horizontal in New York with a slight dip to the south. In Pennsylvania, the folds, which are so evident in the Valley and Ridge region, gradually die out westward in the Plateau. The strata of the Plateau Province have been disturbed but slightly from their original altitude and lie nearly horizontal in most places. The gentle folding is recognizable over broad regions, however. In the Appalachian Plateau, the orientation of the long axes of the folds is northeasterly and, owing to the subsequent development of streams, the topographic features trend in the same direction. The general drainage pattern is dendritic, which has been modified slightly by glaciation and the structural attitudes of the rock strata.

A large part of its northern area has been glaciated. The former presence of the ice sheet is recognized by the glacial drift that covers the uplands with till or unsorted glacial material and fills the valleys to great thicknesses with stratified sand and gravel and ancient lake deposits of silt and clay. In the unglaciated part of the Plateau, it is extremely rugged and the valleys are generally V-shaped. The more resistant layers of rock, the conglomerates and sandstones, outlast the more erodible shales, limestones, and coals, and stand out as ridges with a relief of from 500 to 1,800 feet above the adjacent valleys. Its plateau character, however, is still distinctly recognized from the tops of the hills that rise to an elevation of 1,500 to 2,500 feet or more, and contain a large amount of forest land.

In the New York State and northern Pennsylvania portions of the basin, the effects of glaciation have produced a more subdued topography. Here the valleys are U-shaped and gentle in contrast to the more rugged features and more uneven shapes in the unglaciated area. The hills in the glaciated area, as a rule, rise from 500 to 800 feet above the valleys, with comparatively steep, symmetrical slopes.

The general drainage pattern in the Appalachian Plateau is dendrites (tree shaped). This has been modified slightly by glaciation and rockstrata. This dendrictic drainage pattern also is evident in the Piedmont Plateau and Coastal Plain provinces.

CLIMATE

The Chesapeake Bay Basin lies in the global zone of westerly winds in the mean path of tropical air masses from the Gulf of Mexico. The Appalachian Mountains to the west and the Atlantic Ocean to the east have a significant influence on the region's climate. The interaction between northward moving warm air masses from the Gulf and eastward progressing continental air masses is conducive to the development of rapid climatic changes and major storms. Precipitation is generally plentiful throughout the region.

The overall climate of the region is humid, with four distinct seasons, and is characterized by frequent weather changes. Along the coast, the climate is moderated substantially by the effects of the ocean and large bays, in contrast to inland portions, particularly the mountain ranges, where more marked extremes in temperature and precipitation occur.

During the winter, onshore winds tend to maintain higher temperatures in coastal areas, because the ocean retains heat longer than the land mass. Conversely, summers are cooler along the coast because of the slower rate of heat absorption by the Atlantic Ocean.

Winds are deflected and guided by ridges and valleys which have a general north-to-south orientation. Extreme variations in low temperatures, snowfall, frost penetration and length of growing season, are the result of this general north-south movement, as well as factors such as latitude, altitide and proximity to the coast. The following detailed descriptions are based on information contained in the North Atlantic Regional Water Resources Study.

Temperature

The average annual temperature in the Chesapeake Bay Basin varies from about 45°F in the northern part of the Susquehanna River Basin to 61°F in Virginia (see Figure C-II-3). January and February are the coldest months with mean monthly temperatures ranging from 22°F to 29°F in the north and mountain areas to 40°F to 44°F in Virginia and along the coast. Minimum recorded temperatures include -39°F at Laurenceville, Pennsylvania; -30°F at Bayard, West Virginia; and -26°F near Hancock, Maryland.

The warmest temperatures occur in July, ranging from a mean of 67°F in the mountains to 79°F in Virginia. The maximum recorded temperature was 110°F at Columbia, Virginia, and several locations have reported highs of 109°F.

Temperatures exceeding 90°F occur on the average of 3 or 4 days of the year in the Susquehanna Basin and on approximately 10 days of year in the southern portions of the basin. Temperatures averaging below 32°F during the day occur for about 20 to 35 days per year.

Precipitation

Average annual precipitation in the Chesapeake Bay Basin varies from approximately 30 to 52 inches. The average for the Susquehanna Basin is about 40 inch. Average rainfall in this area gradually increases from north to south (see Figure C-II-4).

In the southern portion of the Chesapeake Bay Basin, about 42 inches of rainfall are received each year. It is generally highest near the Atlantic Coast and in the western portion and lowest in the central part. For instance average rainfall is 30 to 35 inches in the foothills of the Alleghany Mountains, about 52 inches in the headwaters of the North Branch Potomac River, and 48 inches at Snow Hill, Maryland.

There is a distinct seasonal variation in precipitation. The maximum rainfall occurs in the summer (12 to 13) inches and the minimum in the fall and winter (about 9 inches). Spring rainfall averages about 10 to 11 inches.

Average annual snowfall varies widely, being generally higher in the northern and mountain areas than in the southern and coastal areas (see Figure C-II-5). About 10 to 15 inches of snow falls on the coast and in the south. The northern and central portions of the Susquehanna Basin average 50 inches annually. A high of 85 inches was recorded at Binghamton and nearly 140 inches at Cortland. In the mountains of West Virginia, nearly 80 inches of snow has fallen in one year.

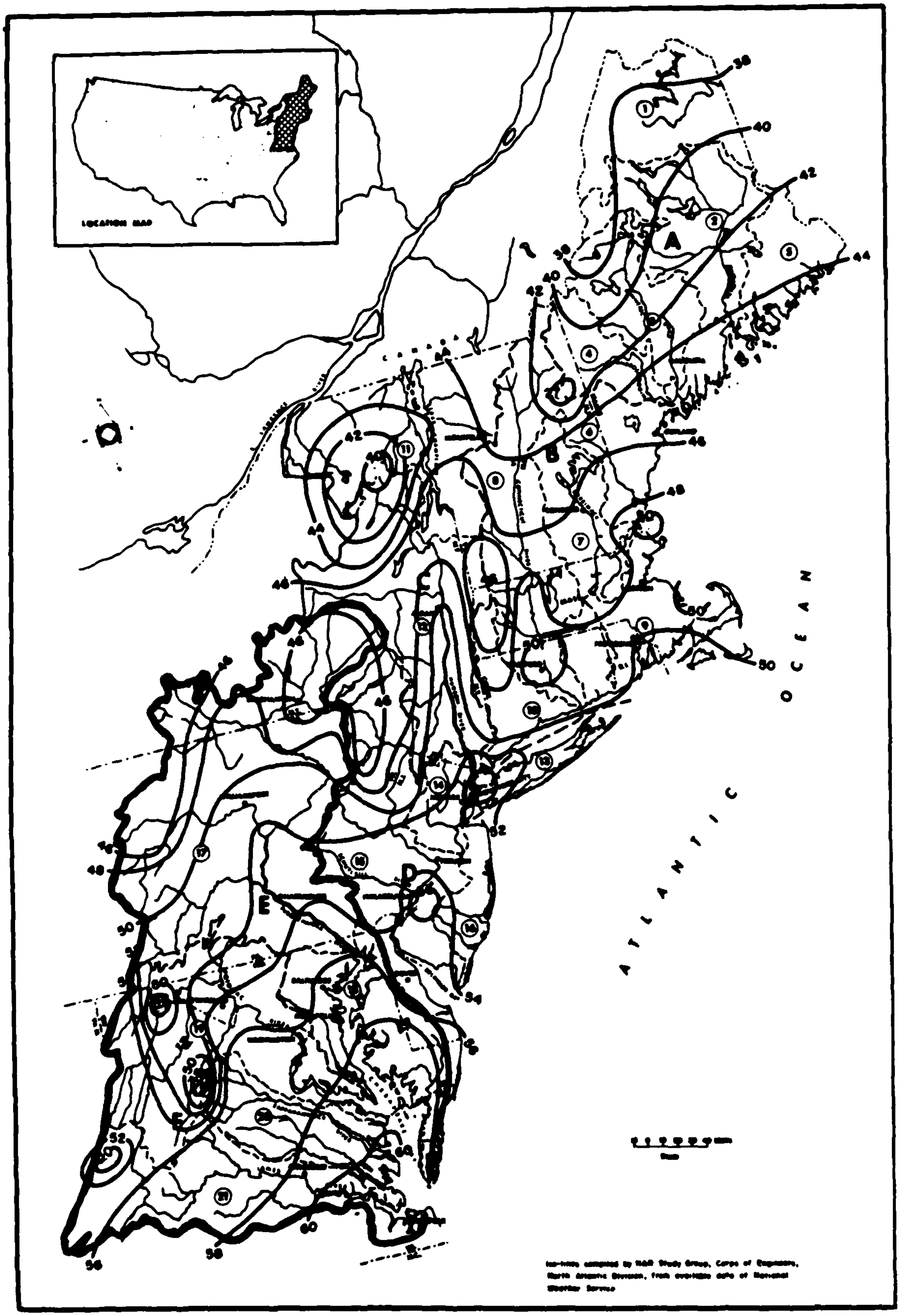


FIGURE C-II-3 AVERAGE ANNUAL TEMPERATURE

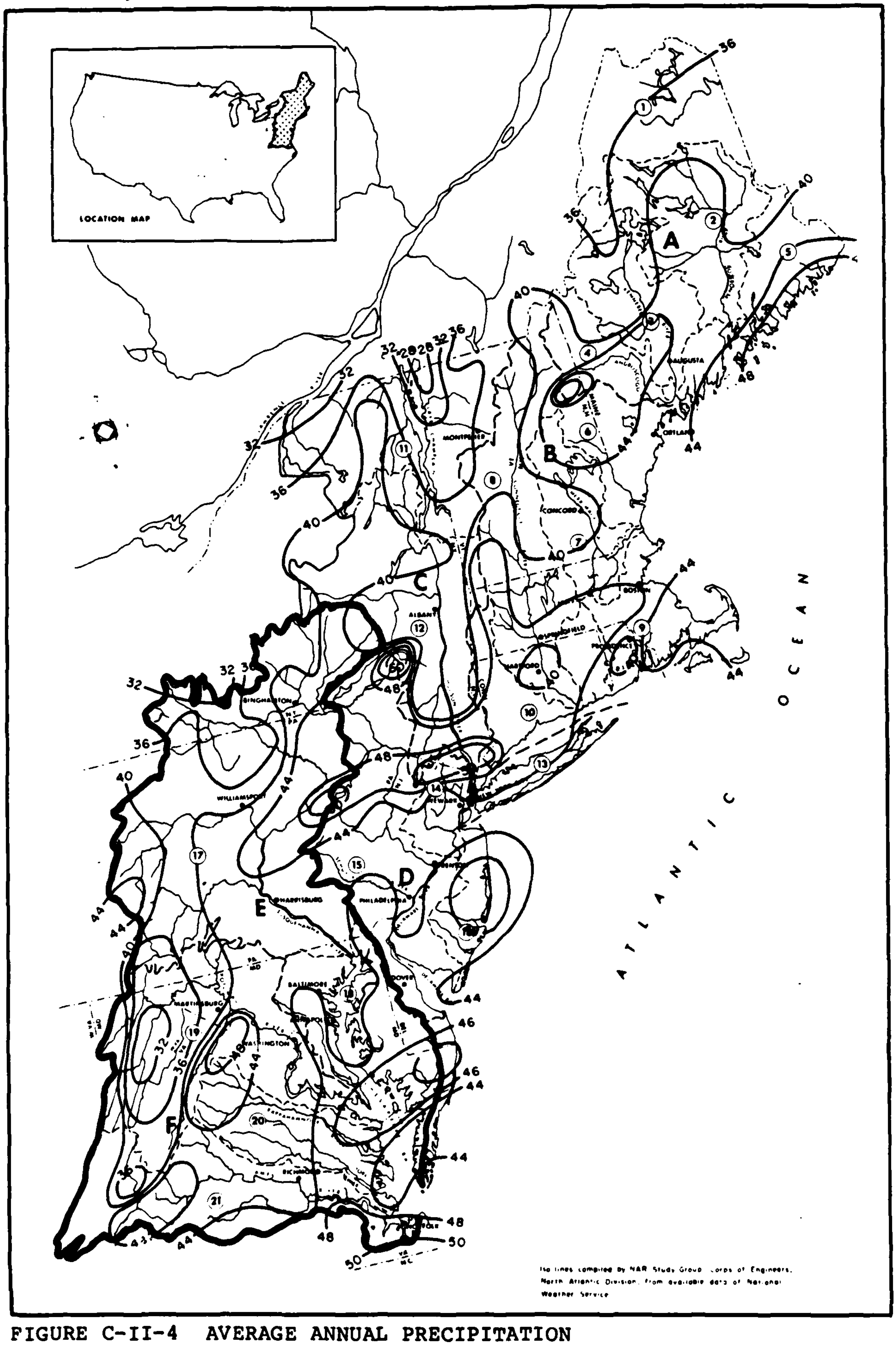


FIGURE C-II-4 AVERAGE ANNUAL PRECIPITATION

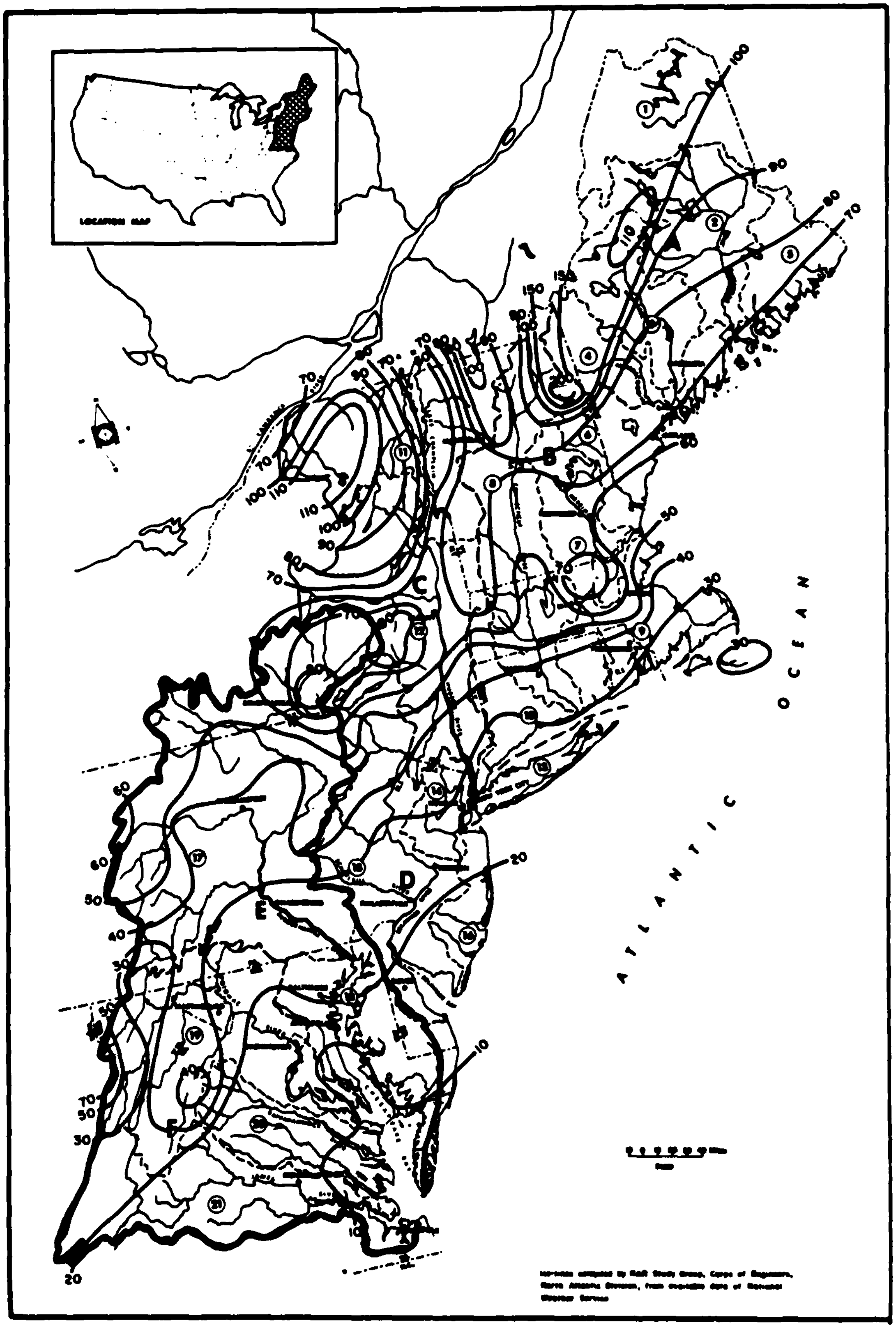


FIGURE C-II-5 AVERAGE ANNUAL SNOWFALL

Three types of storm activity bring precipitation to the Chesapeake Bay Basin. The first type consists of extratropical storms or lows which originate to the west, either in the Rocky Mountains, Pacific Northwest or the Gulf of Mexico. The second is tropical storm or hurricane type activity which originates in the Middle Atlantic or the Carribbean. The third is thunderstorm activity which is almost always local. Thunderstorms bring about the greatest local variation in precipitation.

Sub-normal precipitation occurs quite frequently. The droughts of the early 1930's and 1960's affected the entire Chesapeake Bay Basin. Large deficits in precipitation were prevalent for several years during both of these droughts.

Humidity

Relative humidity is the amount of moisture in the air relative to the amount which would saturate the air at a given temperature and pressure. Since the amount of moisture necessary to saturate the air is greater at higher temperatures, relative humidity may be misleading as to the quantity of moisture present. For example, a relative humidity of 50 percent at 90° F. indicates more moisture content than a relative humidity of 60 percent at 70°F. The wet bulb temperature, which is the temperature of a moist, ventilated, shaded thermometer bulb, is the point of equilibrium between air warmth and the evaporational cooling effect of the moist glass surface of the bulb. Absolute humidity is generally higher at higher wet bulb temperatures (in the above example, the wet bulb readings would be about 75° F. and 60° F. respectively), and can be used more conveniently to indicate comfort or discomfort. An empirical difference exists between the wet bulb temperature and dew point temperature. Dew point temperature is the temperature at which saturation would occur for any actual water content present, if the air were cooled at constant pressure.

Mean relative humidity averages about 70 percent in the Susquehanna River Basin. In that portion of the Chesapeake Bay Basin below the Susquehanna, humidity varies from about 80 percent along the coast to 70 percent in the interior. The averages for January and July are about the same as the annual average, however, there are fairly wide seasonal differences in the diurnal fluctuation. For instance, Washington D.C. has an average humidity of 84 percent at 1:00 a.m. and 93 percent at 1:00 p.m. during July. In January, the respective averages are 70 percent and 56 percent. The mean dew point is lower in the northern portion of the basin than in the southern. During January it is about 15° F. in the north and 30° F. in the south. In July it varies from 60° F. to 65° F.

Evaporation

Evaporation rates depend upon a number of factors including temperature, atmospheric pressure, wind, water quality and the nature of the evaporating surface. Evaporation tends to decrease with increasing elevation due in part to the decrease in atmospheric pressure and dew point temperatures.

The mean annual lake evaporation varies from about 27 inches in the northern part of the Susquehanna Basin to 40 inches in Virginia. From north to south, 70 percent to 76 percent of the evaporation occurs from May to October. Evaporation from the Chesapeake Estuary has been estimated at 36 to 40 inches per year.

Wind

The prevailing winds are westerly during the winter and shift to the southwest during the summer months. The average velocity ranges from 8 mph inland to 12 mph along the Bay and the coast line. Winds as high as 80 mph occur during the passage of hurricanes, but much of the severe wind damage is sustained during thunderstorms, which occur about 35 times annually.

CHAPTER III

HISTORIC LOW STREAMFLOW INFORMATION

GENERAL DESCRIPTION OF THE HYDROLOGIC CYCLE

The major interests of this appendix are confined to the hydrology of surface runoff which result from the precipitation phase of the hydrologic cycle, and to its variations in quantities. To best discuss these variations, an understanding of the hydrologic cycle is necessary. In a descriptive manner, the hydrologic cycle is the general circulation of water from the seas, to the atmosphere, to the ground, and back to the seas, or, evaporation—condensation—precipitation. Water from oceans, lakes and rivers, land areas, vegetation, glaciers, ice, and snow evaporates into the atmosphere where it rises and is cooled. Condensation of the vapor results in cloud formations in which water particles form and eventually fall as precipitation. Some of the falling precipitation evaporates as it falls. Of the precipitation reaching the earth's surface, some is retained where it falls and is evaporated, some infiltrates through the soil surface, some flows overland and enters stream channels as runoff, and some is absorbed by plants through their roots systems and returned to the atmosphere through the process of transpiration. When the absorption capacity of a given soil is satisfied, surface runoff occurs that reaches surface channels by the overland route. It is the first element of runoff that reaches the streams and is a major factor in the occurence of floods. The water that infiltrates into the soil antecedent to the surface run-off period creates a ground water table from which water moves over a long period of time to eventually emerge as surface water. Ground water is the primary source of streamflow during dry weather periods, and its magnitude and variation establish the low flow characteristics of streams. Thus, depending on local topography, geology, and vegetal cover, it can be expected that flow characteristics of streams are highly individual and variable in nature.

A drought is a period of abnormally dry weather of sufficient duration that the lack of water causes a serious hydrologic imbalance resulting in problems such as crop damage, water supply shortages, etc. Low streamflow is caused by a combination of meteorologic factors (e.g., precipitation rates, temperature, amount of wind movement, and amount of cloud cover) and environmental conditions (e.g., recharge rates, soil moisture, and depressed groundwater levels). Generally, the term applies to relatively extensive time periods and areas.

A severe drought situtation arises from several years of extended low flow periods. Typically, the drought begins with a dry summer season resulting in below-normal surface runoff. During the dry period, the groundwater table drops, and the natural discharge of groundwater into surface water systems is reduced. The combination of decreased runoff and reduced groundwater discharge yields low streamflow during summer and fall. The annual snowmelt and spring rainfall produce increased streamflows and alleviate drought effects temporarily. However, the influx of water does not replenish the groundwater aquifer fully, and the groundwater level remains below normal. Another season of dry weather leads to critically low flows. As the cycle of dry weather, low flows, and insufficient groundwater recharge continues, the effects of the drought worsen. The cycle is broken by a large rainfall or series of rainfalls sufficient to allow the groundwater table to return to a normal level.

The U.S. Geological Survey (USGS) compiles the streamflow records from about 80 gages located at numerous sites throughout the Basin. These data are contained in the USGS WATSTORE computer file which stores daily flow records for all of the USGS stream gages. The USGS record is based on a climatic year beginning on 1 April and ending on 31 March. The USGS has set up the climatic year system in order to show a late autumn-early winter drought in the same analytical year.

Because of the large area (and the varying types of terrain) to be evaluated, eleven gaging stations were chosen for this analysis. Table C-III-1 presents the gage numbers, names, drainage areas, and periods of record for the gages chosen. As can be seen in Figure C-III-1, there are six gages on the Western Shore, one on the Susquehanna River, and four gages on the Eastern Shore.

TABLE C-III-1

STREAM GAGES

Gage Numbers	Location	Drainage Area ($mi.^2$)	Period of Record
2035	James River at Cartersville, Va.	6,257	1926-1980
6745	Mattaponi River near Beulahville, Va.	601	1942-1980
6680	Rappahannock River near Fredericksburg, Va.	1,596	1911-1980
6385	Potomac River at Point of Rocks, Md.	9,651	1943-1980
5925	Patuxent River near Laurel, Md.	132	1945-1980
5890	Patapsco River at Hallofield, Md.	285	1946-1981
5705	Susquehanna River at Harrisburg, Pa.	24,100	1891-1981
4950	Big Elk Creek at Elk Mills, Md.	52.6	1933-1980
4910	Choptank River near Greensboro, Md.	113	1949-1981
4870	Nanticoke River near Bridgeville, Md.	75.4	1944-1981
4850	Pocomoke River near Willards, Md.	60.5	1951-1981

HISTORIC HYDROGRAPHS

One of the data sets which can be gotten from the WATSTORE files is yearly average flows based on all the daily values over the course of the climatic year. The average yearly flows are presented as historical hydrographs in Figures C-III-2 through C-III-22 (even numbers). The mean yearly flow is represented on each figure by a horizontal line.

If the data point for a certain year falls above that line, it can be classified a "wet" year. Likewise, if a year falls below the line, it can be called a "dry" year. Consecutive dry years comprise a drought. The hydrographs for all gages show a series of dry years in the mid-1960's. For the four gages that have records for the early 1930's, another drought period is evident. By examining the length of the dry period, and the distance below the mean line, various droughts can be compared for severity.

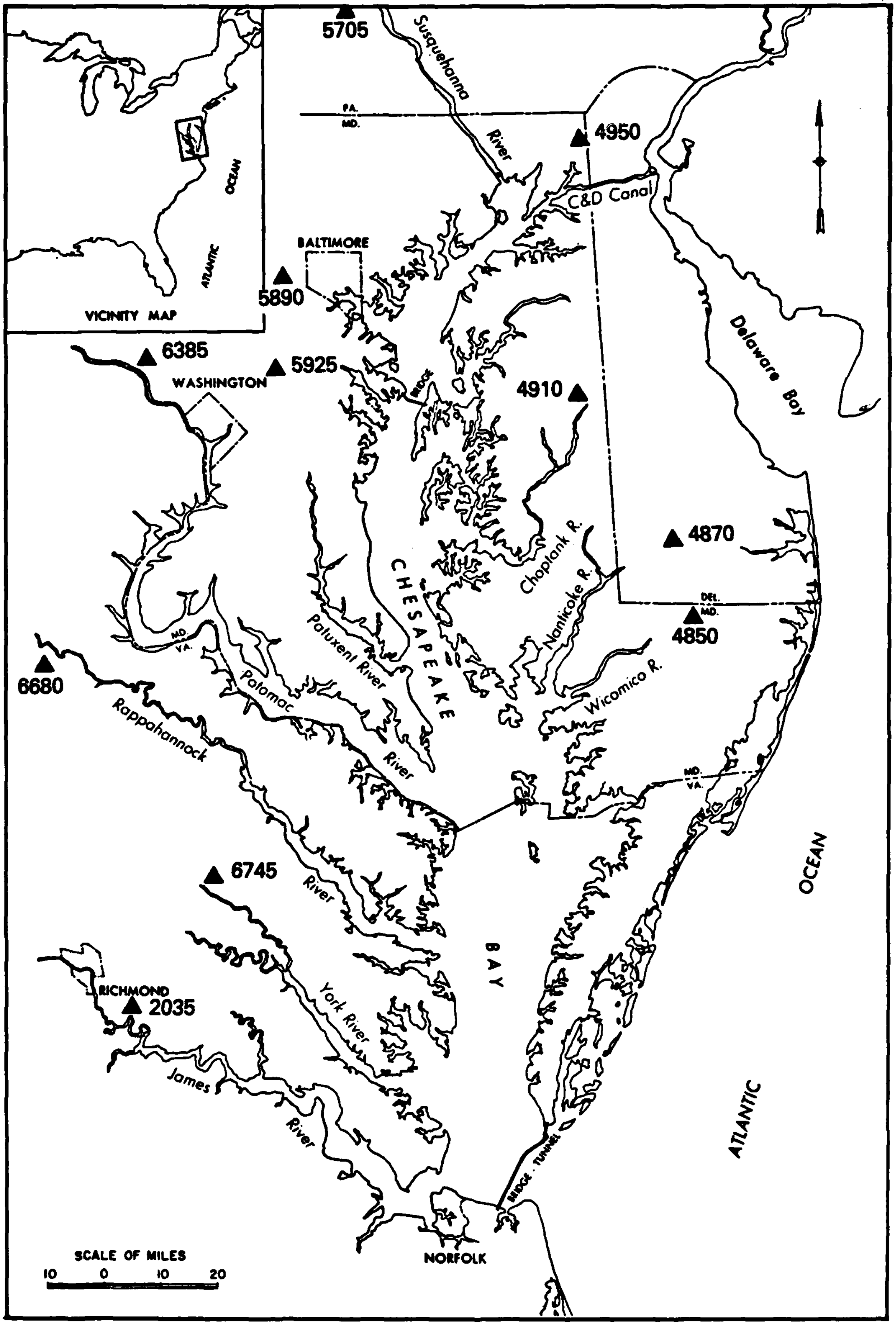


FIGURE C-III-1 GAGE LOCATIONS

In all eleven historic hydrographs, the years around the mid-1960's have lower than average flows. The area of the curves representing the time that the flows were below normal has been filled in, representing the 1960's drought. The hydrograph for the James, Rappahannock, Potomac, and Susquehanna Rivers show data from a long enough period of record that the 1930's drought can be compared to the 1960's drought. On these hydrographs, the 1930's drought has been cross-hatched.

The hydrographs for the James and the Rappahannock Rivers show that the mean annual flow was considerably less in the 1930's drought than in the 1960's drought. The hydrographs for the Potomac and the Susquehanna Rivers show that the two droughts are more equal, with the 1960's drought being somewhat drier. It may be inferred from this that the 1930's drought was more severe in the southern part of the basin than in the northern part, and the converse is true for the 1960's drought. (It should be noted, however, that in all cases the "dry" period is much longer for the 1960's drought.)

LOW FLOW FREQUENCY CURVES

A low flow frequency curve is prepared using the same methods as for a flood frequency curve, except that minimum flows are used rather than peak flows. Where a flood frequency curve shows what may be short term events (e.g., flash floods), a low flow frequency curve indicates the probability of having a particular flow which is not exceeded for a certain duration of days. Low flow frequency curves are shown for the 11 gaging stations in Figures C-III-3 through C-III-23 (odd numbers).

The curves present low flow non-exceedence frequencies, annual by climatic year, for the eleven gages. In these figures, the vertical axis is cubic feet per second (cfs) and the lower horizontal axis is non-exceedance frequency. The curves for the James River at Cartersville gage show that there is a 10 percent probability that in any year there will be a seven day period where the average flow does not exceed 600 cfs. There is a 99 percent probability that there will be a seven day period with an average flow that does not exceed 3,000 cfs. The curves displayed are for durations of 7 days, 30 days, 90 days, and 365 days.

LOWEST RECORDED AVERAGE FLOWS

Tables C-III-2 through C-III-12 list the 10 lowest recorded average flows for the 7 day, 30 day, 90 day, and 365 day durations. The lowest 365 day average flows represent the values plotted on the historic hydrographs. As in a previous example, there is a 10 percent probability in any year that for the James River at Cartersville, there will be a seven day period with an average flow less than 600 cfs. The table shows that this has happened 7 times.

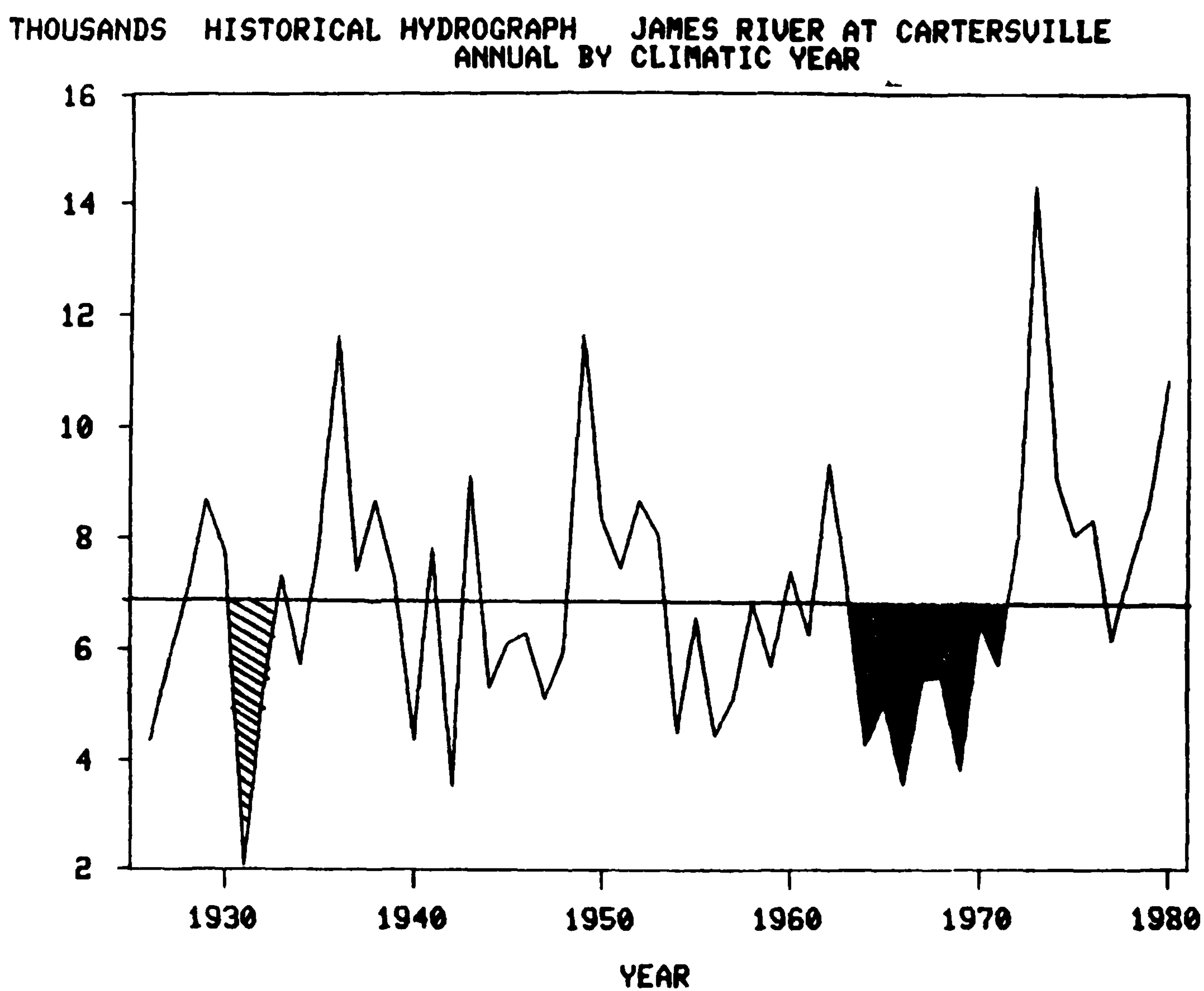
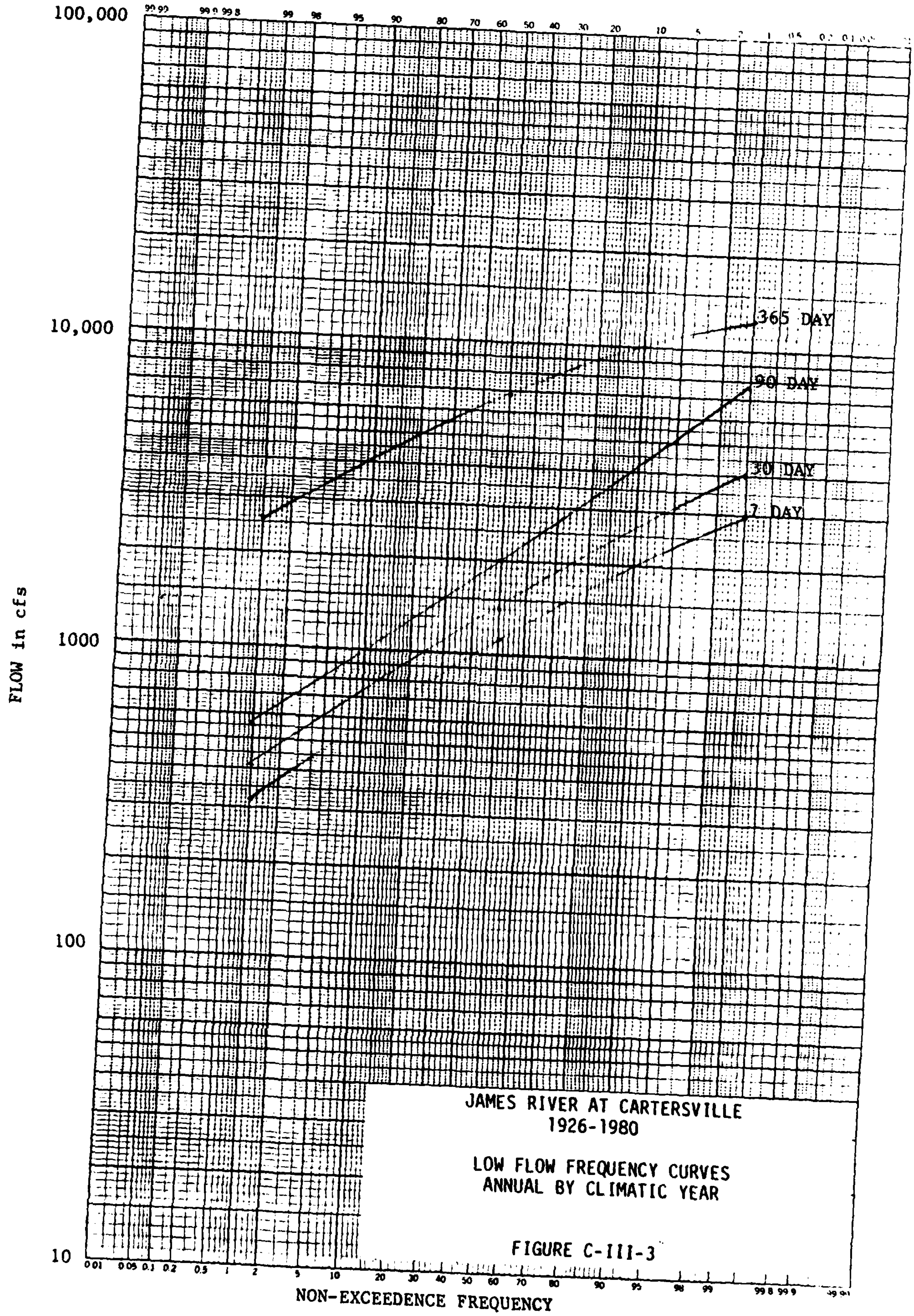


FIGURE-C-III-2



JAMES RIVER AT CARTERSVILLE
1926-1980

LOW FLOW FREQUENCY CURVES
ANNUAL BY CLIMATIC YEAR

FIGURE C-III-3

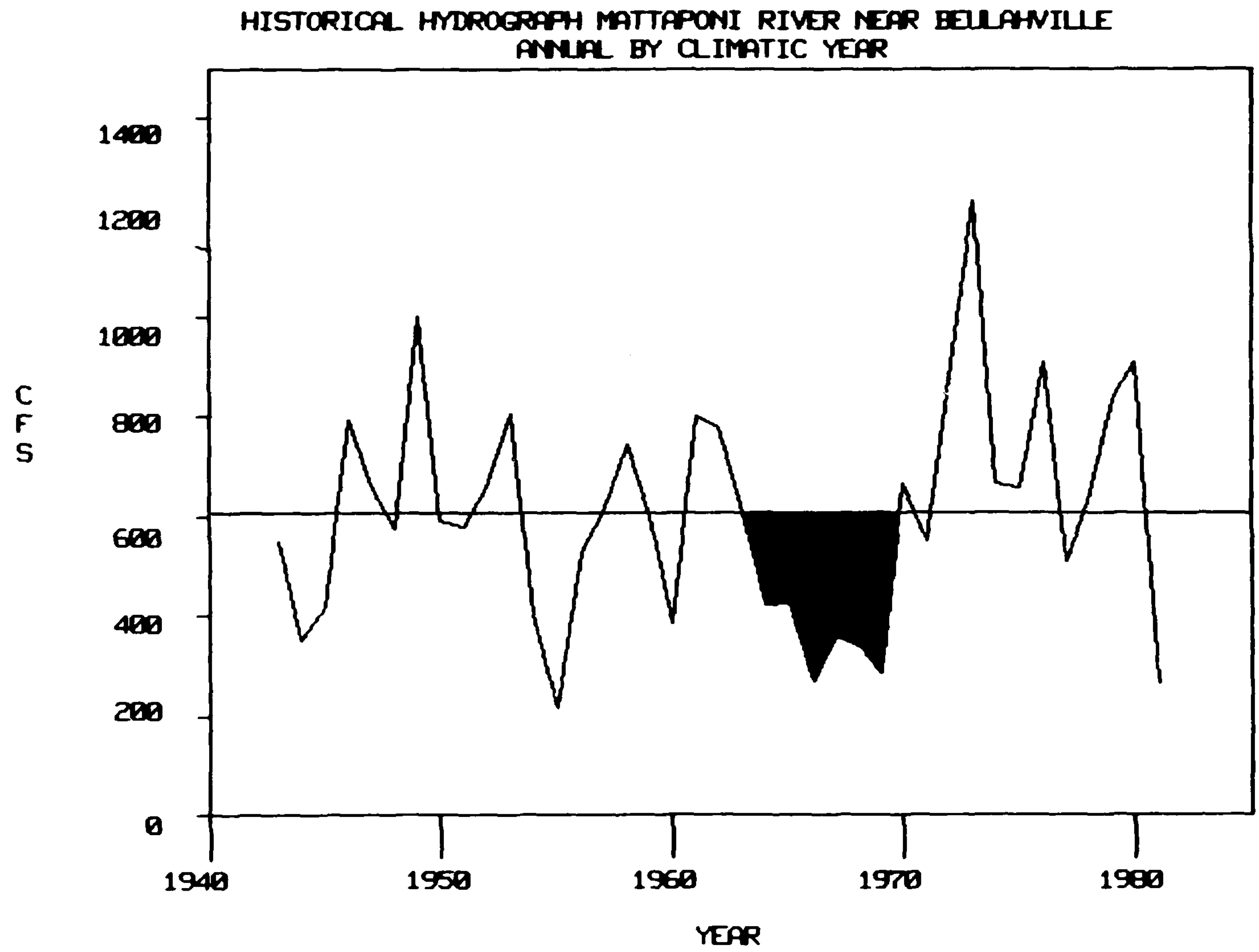
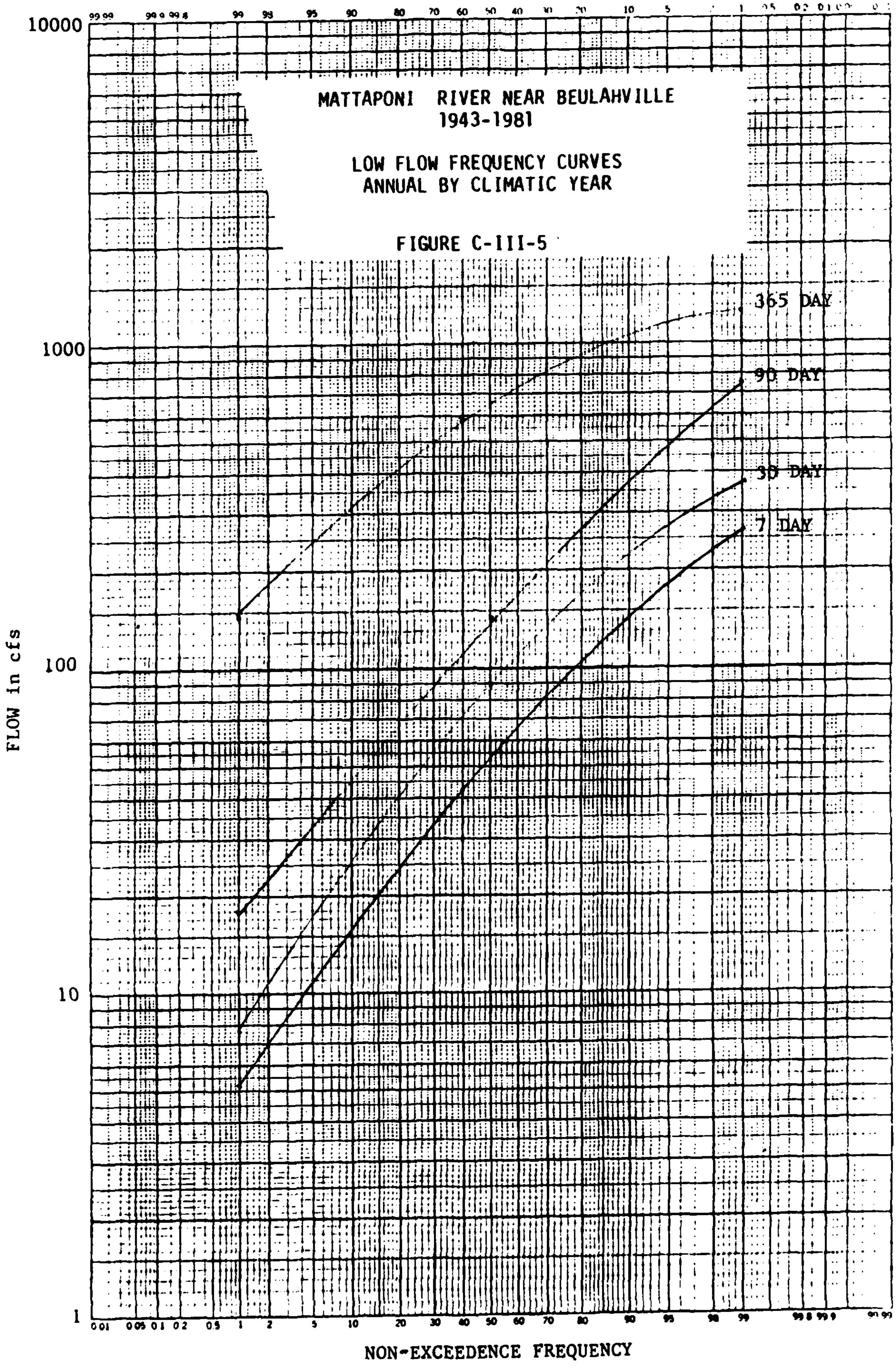


FIGURE C-III-4


MATTAPONI RIVER NEAR BEULAHVILLE
1943-1981
LOW FLOW FREQUENCY CURVES
ANNUAL BY CLIMATIC YEAR
FIGURE C-III-5
365 DAY
90 DAY
30 DAY
7 DAY
10000
1000
100
10
1
FLOW in cfs
NON-EXCEEDENCE FREQUENCY

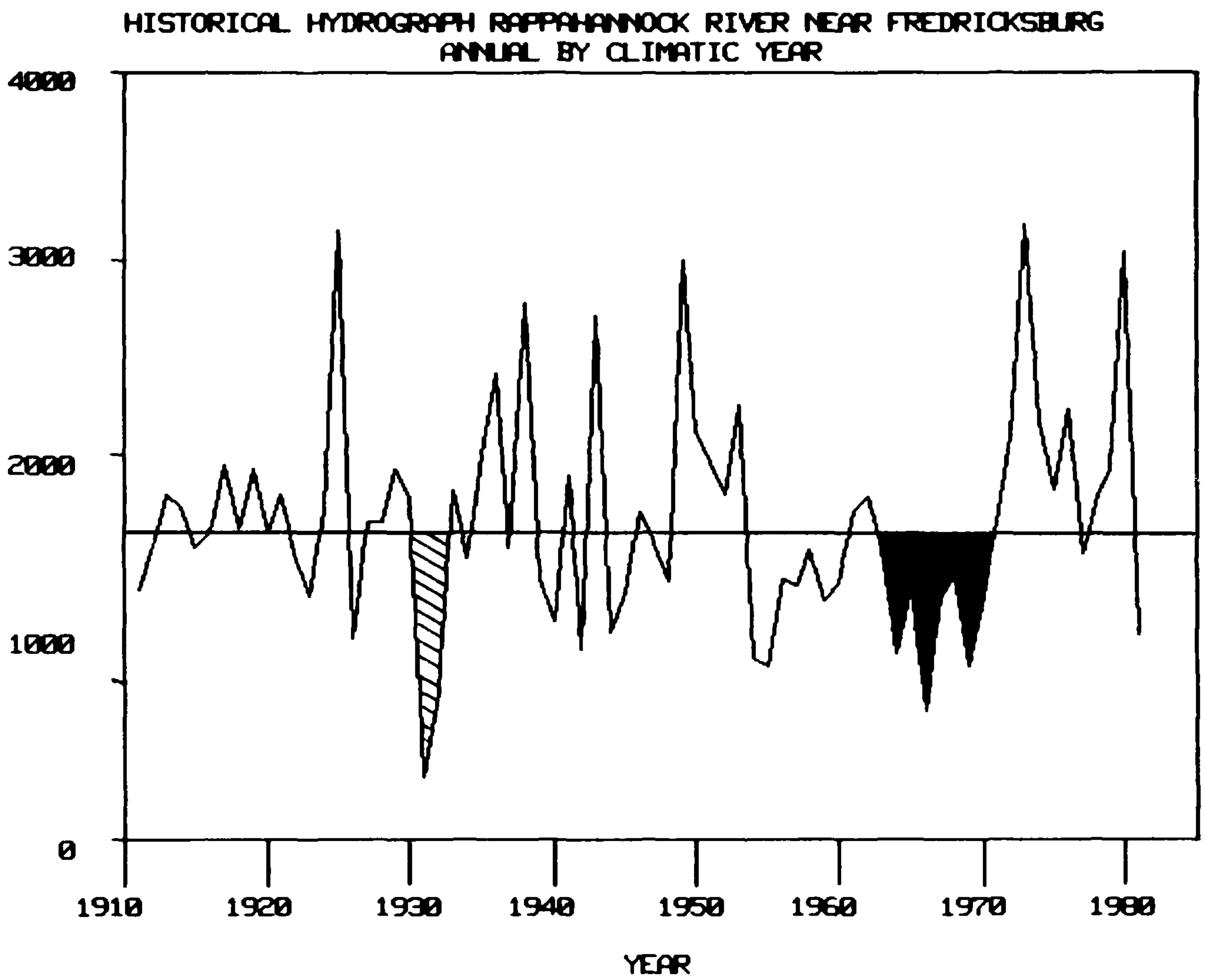


FIGURE C-III-6

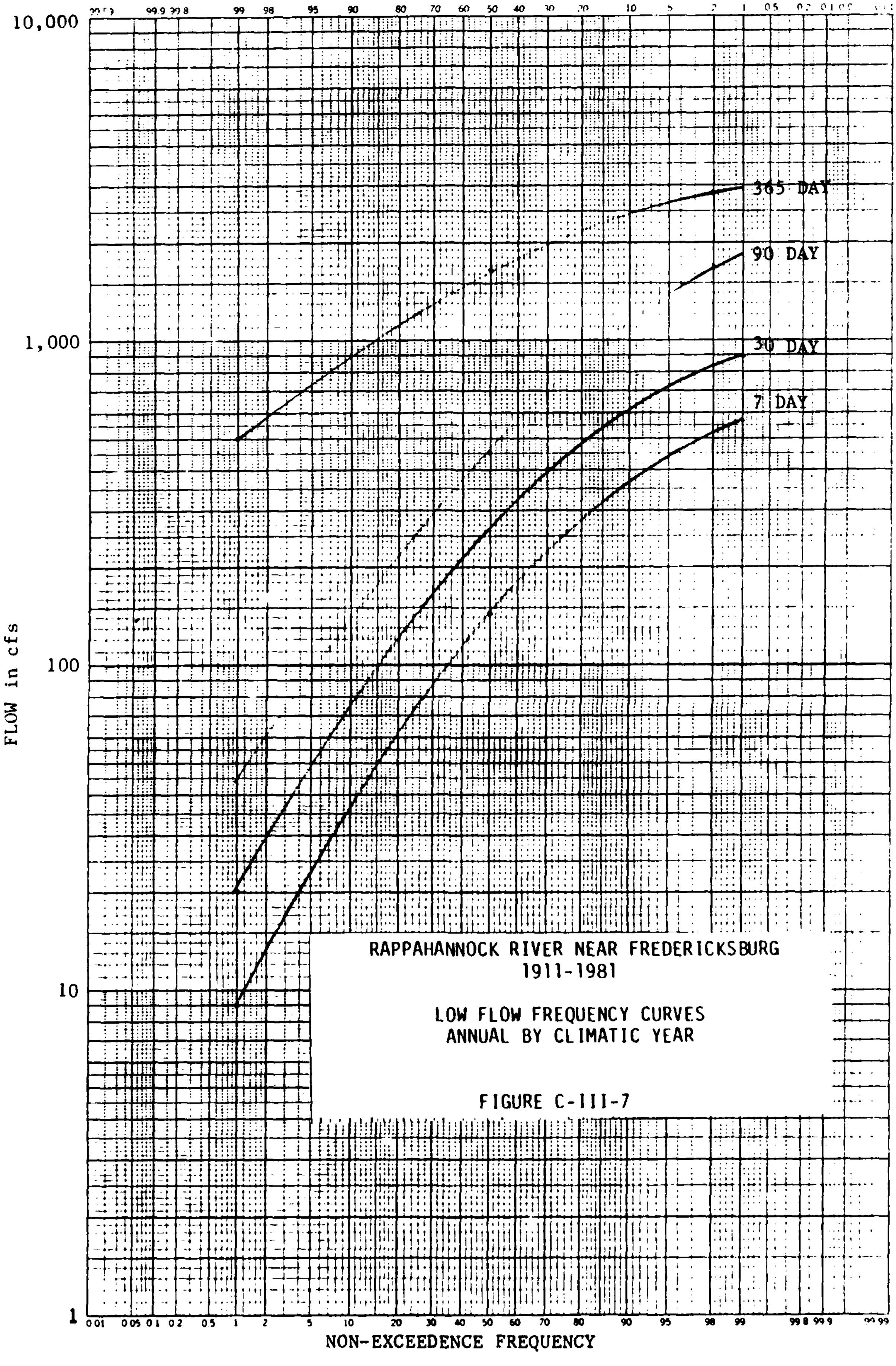


FIGURE C-III-7

HISTORICAL HYDROGRAPH PATUXENT RIVER NEAR LAUREL
ANNUAL BY CLIMATIC YEAR

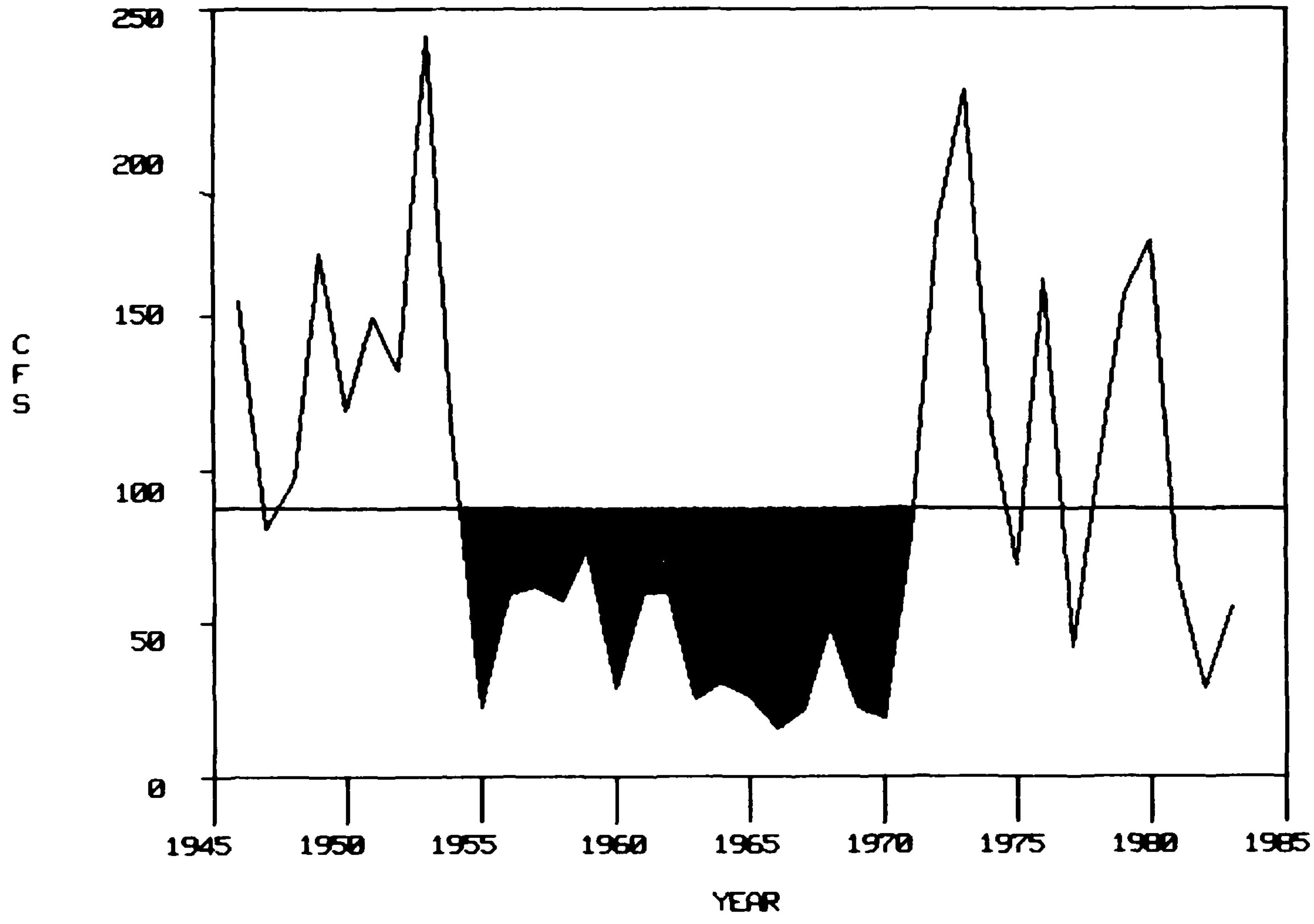


FIGURE C-III-10

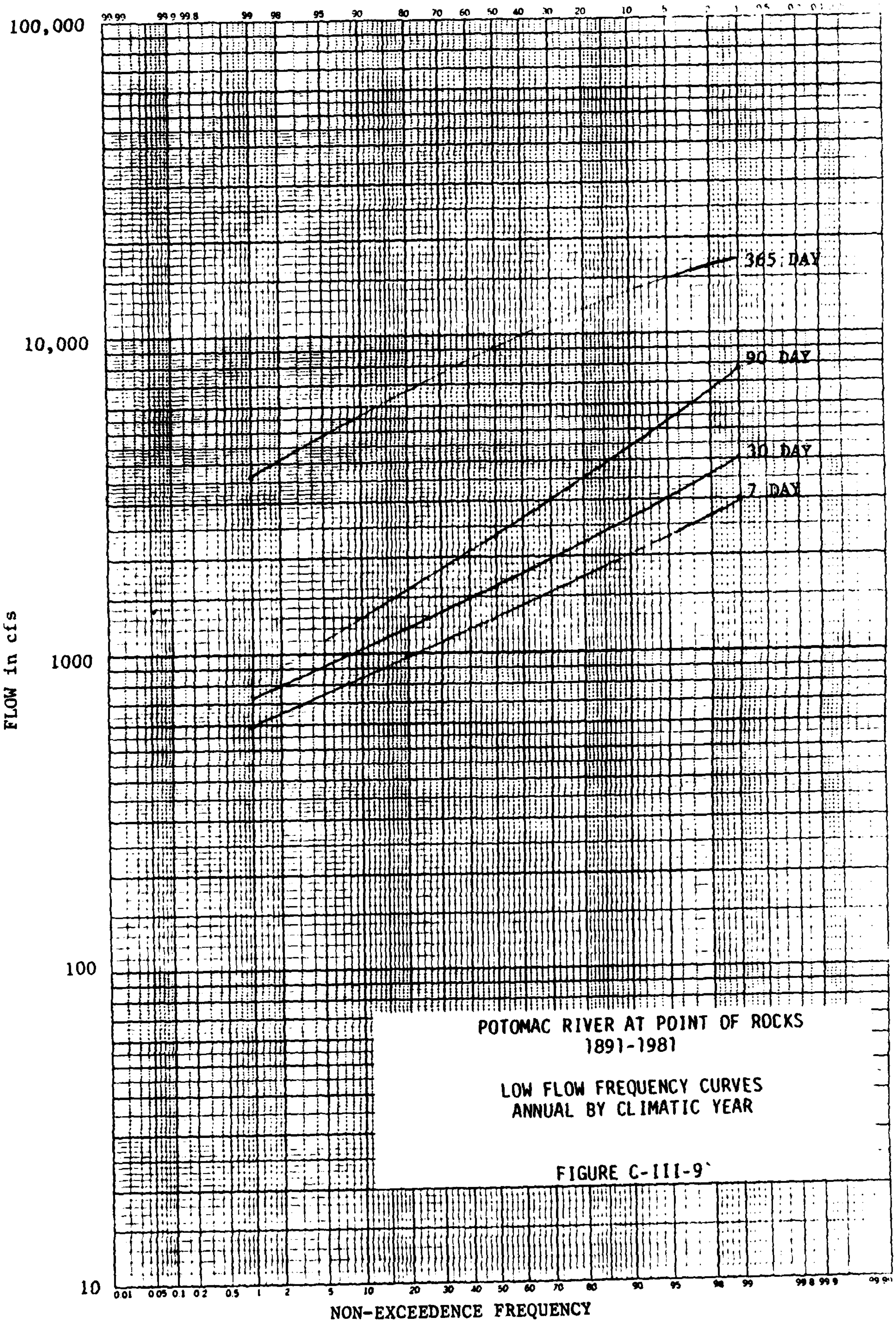


FIGURE C-III-9

THOUSANDS HISTORICAL HYDROGRAPH POTOMAC RIVER AT POINT OF ROCKS
ANNUAL BY CLIMATIC YEAR

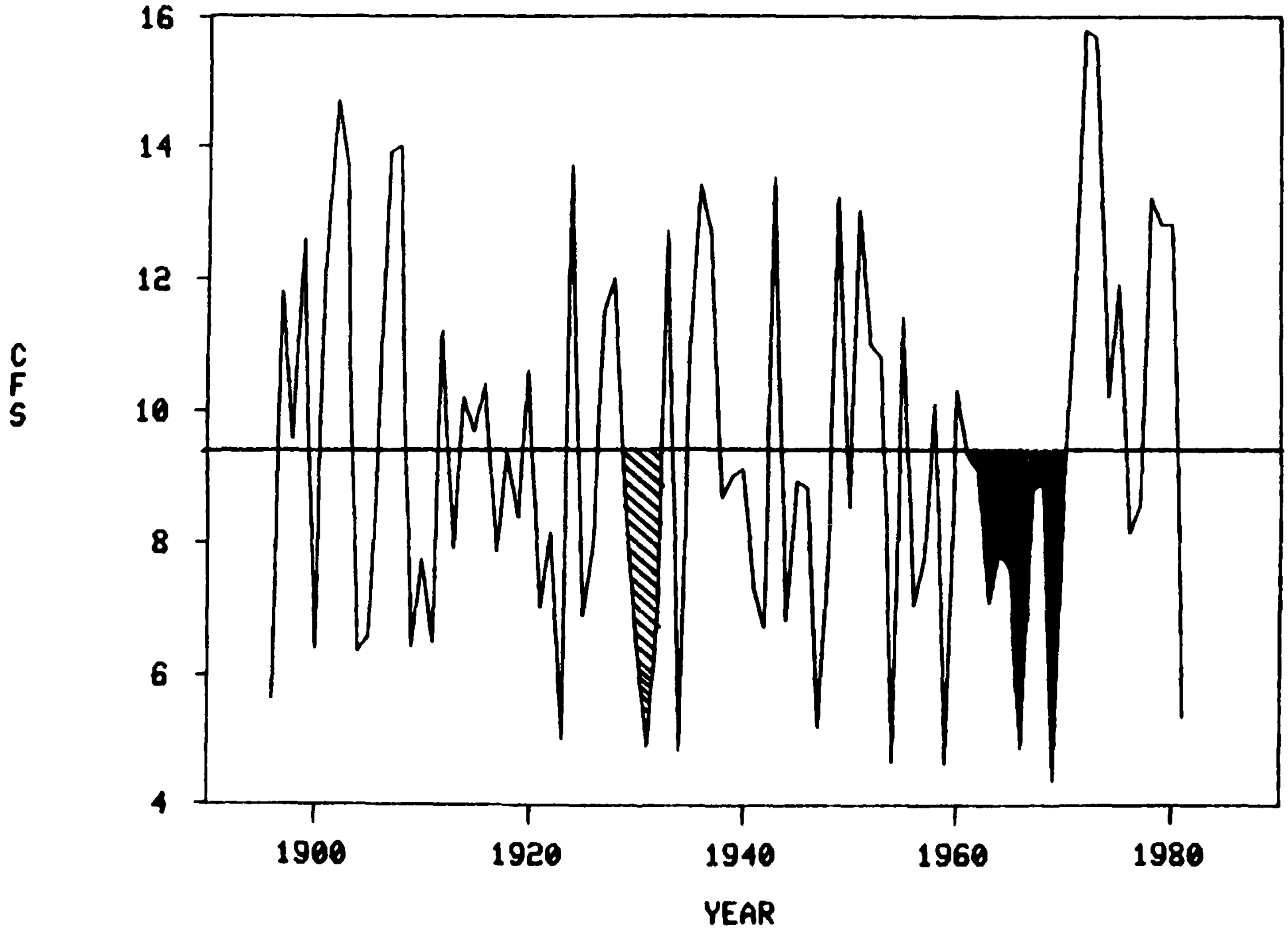
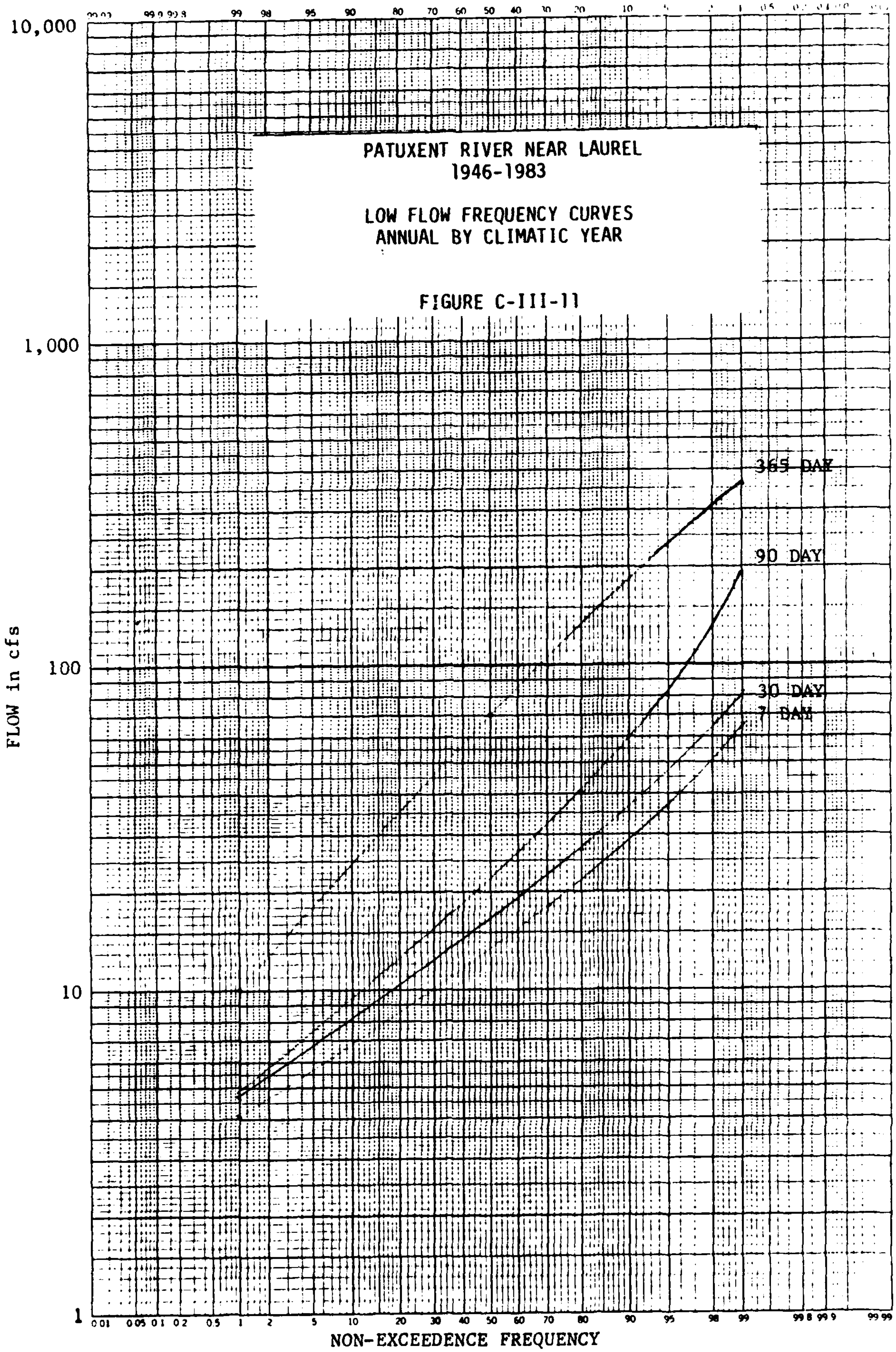


FIGURE C-III-8


PATUXENT RIVER NEAR LAUREL
1946-1983
LOW FLOW FREQUENCY CURVES
ANNUAL BY CLIMATIC YEAR
FIGURE C-III-11
365 DAY
90 DAY
30 DAY
7 DAY
10,000
1,000
100
10
1
FLOW in cfs
NON-EXCEEDENCE FREQUENCY

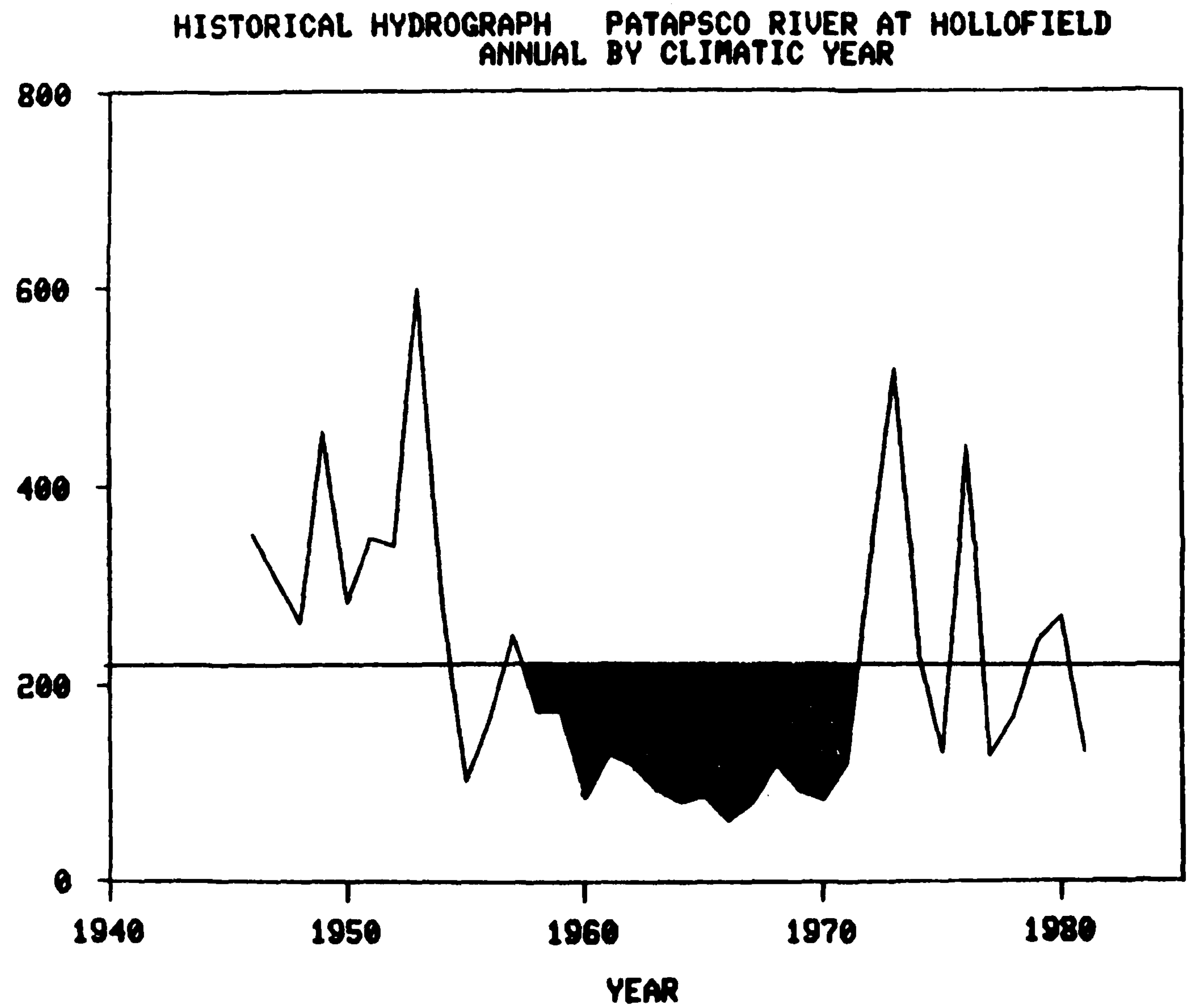
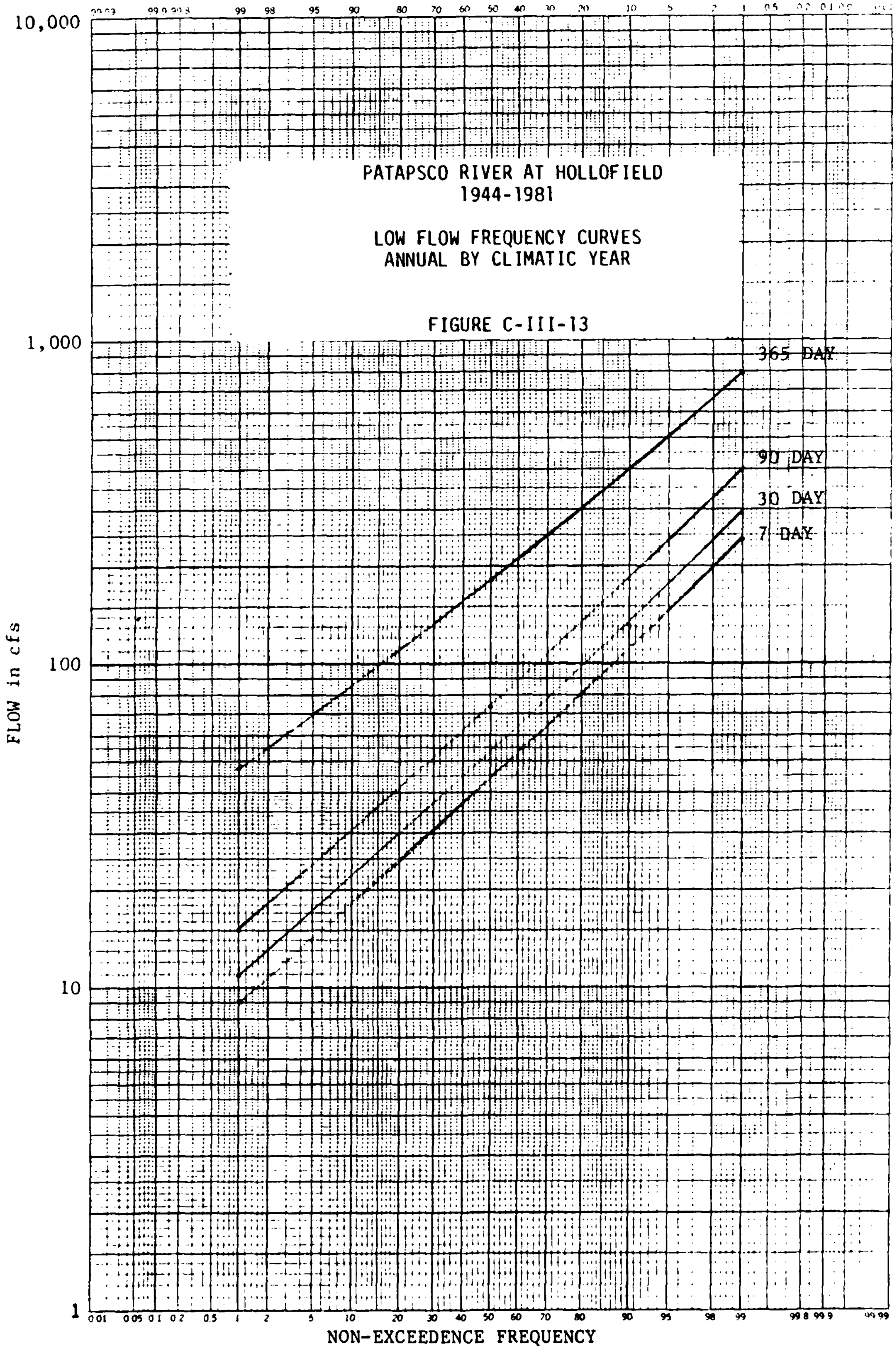


FIGURE C-III-12



PATAPSCO RIVER AT HOLLOFIELD
1944-1981
LOW FLOW FREQUENCY CURVES
ANNUAL BY CLIMATIC YEAR
FIGURE C-III-13
365 DAY
90 DAY
30 DAY
7 DAY
10,000
1,000
100
10
1
FLOW in cfs
NON-EXCEEDENCE FREQUENCY

THOUSANDS HISTORICAL HYDROGRAPH SUSQUEHANNA RIVER AT HARRISBURG
ANNUAL BY CLIMATIC YEAR

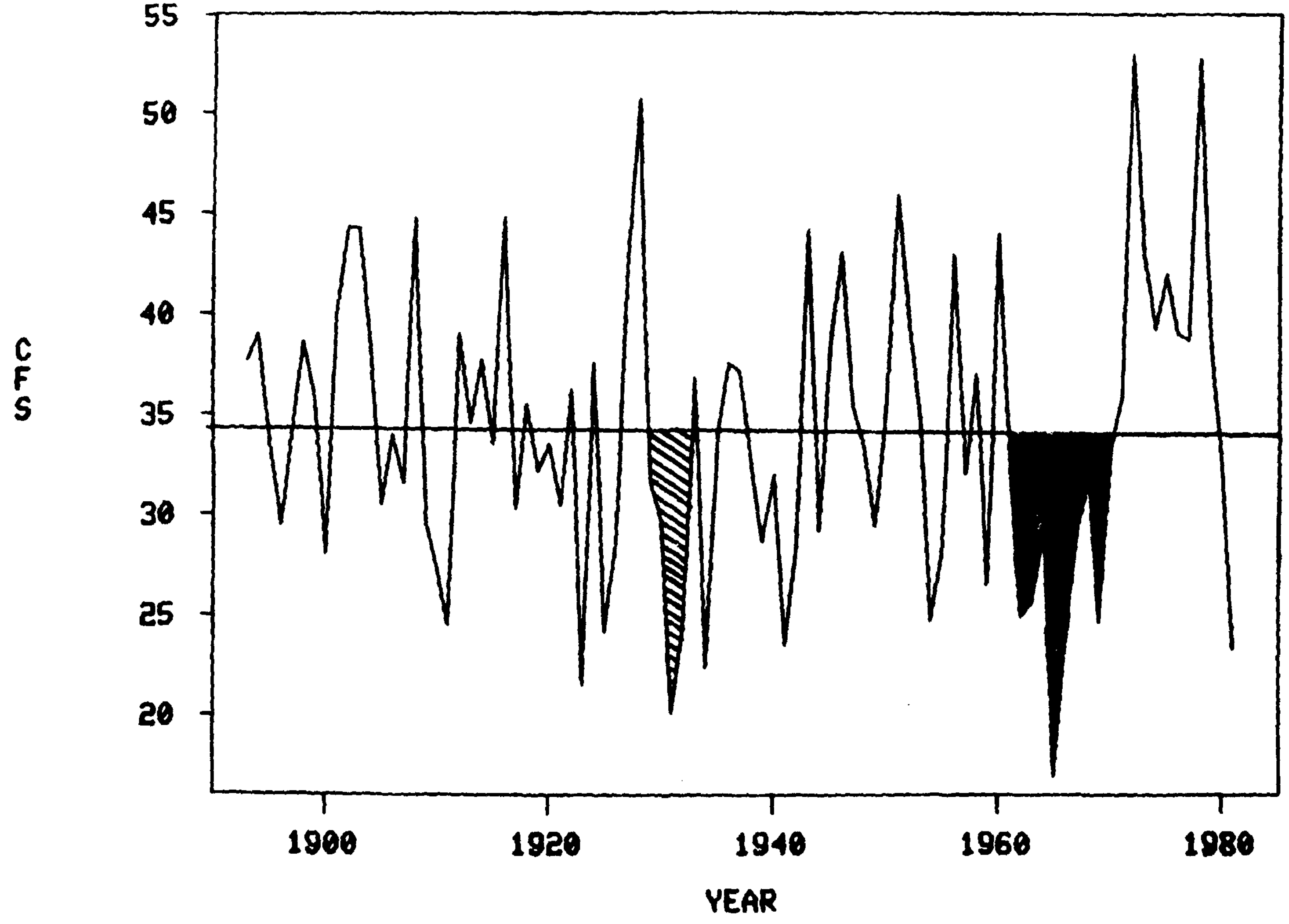
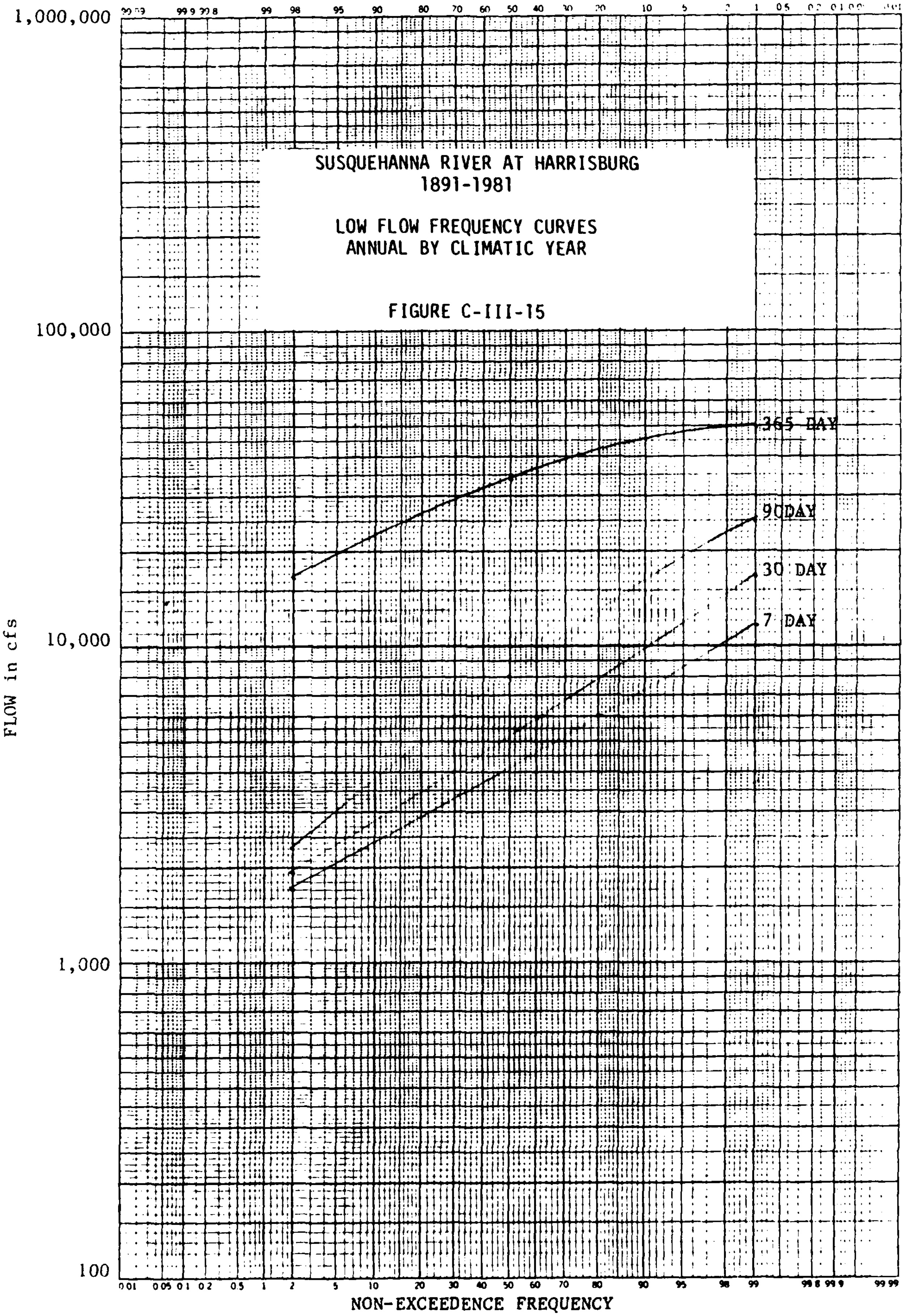


FIGURE C-III-14



SUSQUEHANNA RIVER AT HARRISBURG
1891-1981
LOW FLOW FREQUENCY CURVES
ANNUAL BY CLIMATIC YEAR
FIGURE C-III-15
1,000,000
100,000
10,000
1,000
100
FLOW in cfs
365 DAY
90DAY
30 DAY
7 DAY
NON-EXCEEDENCE FREQUENCY

HISTORICAL HYDROGRAPH BIG ELK CREEK AT ELK MILLS
ANNUAL BY CLIMATIC YEAR

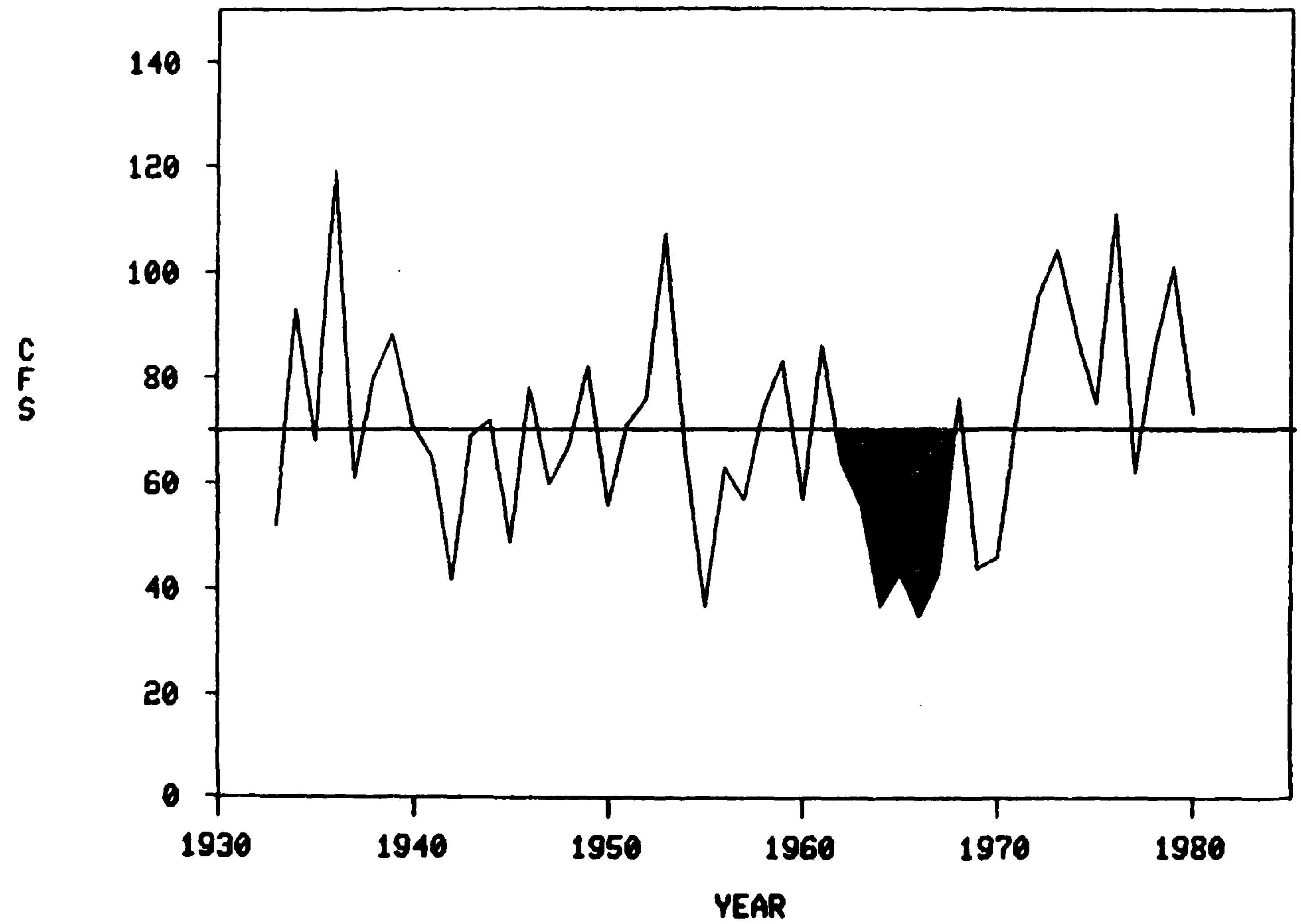
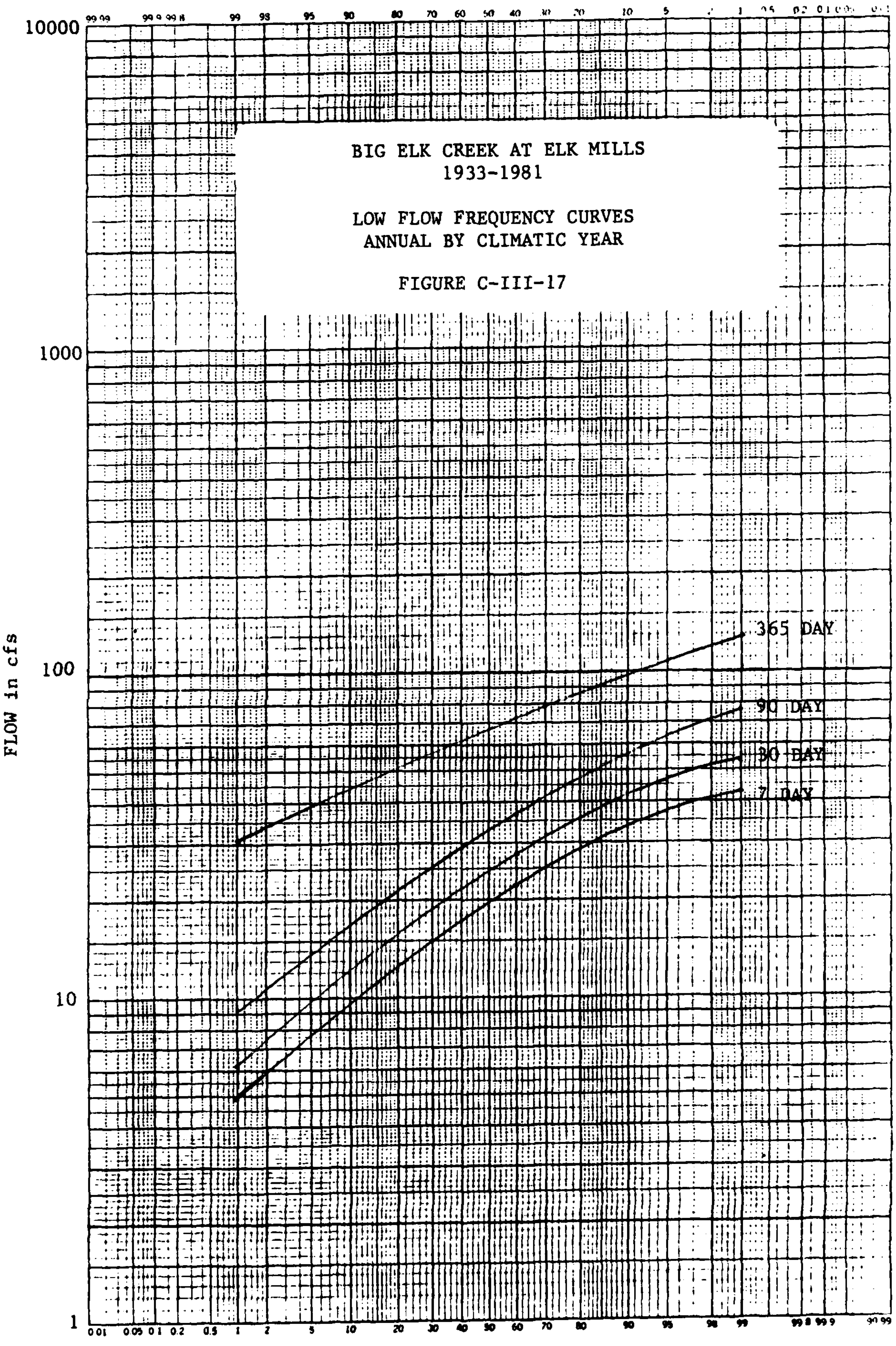


FIGURE C-III-16


BIG ELK CREEK AT ELK MILLS
1933-1981
LOW FLOW FREQUENCY CURVES
ANNUAL BY CLIMATIC YEAR
FIGURE C-III-17
365 DAY
90 DAY
30 DAY
7 DAY
FLOW in cfs
10000
1000
100
10
1
NON-EXCEEDENCE FREQUENCY

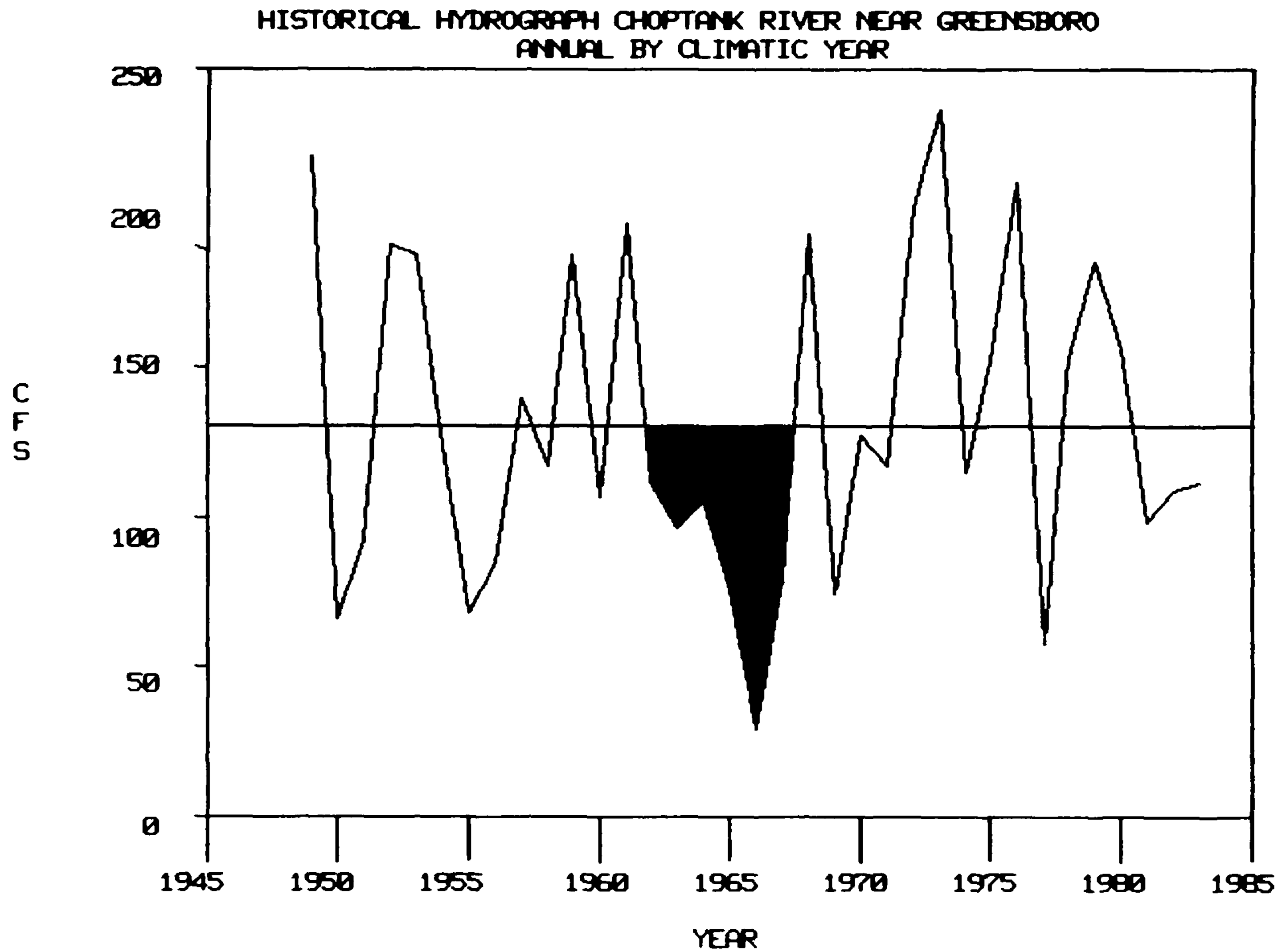
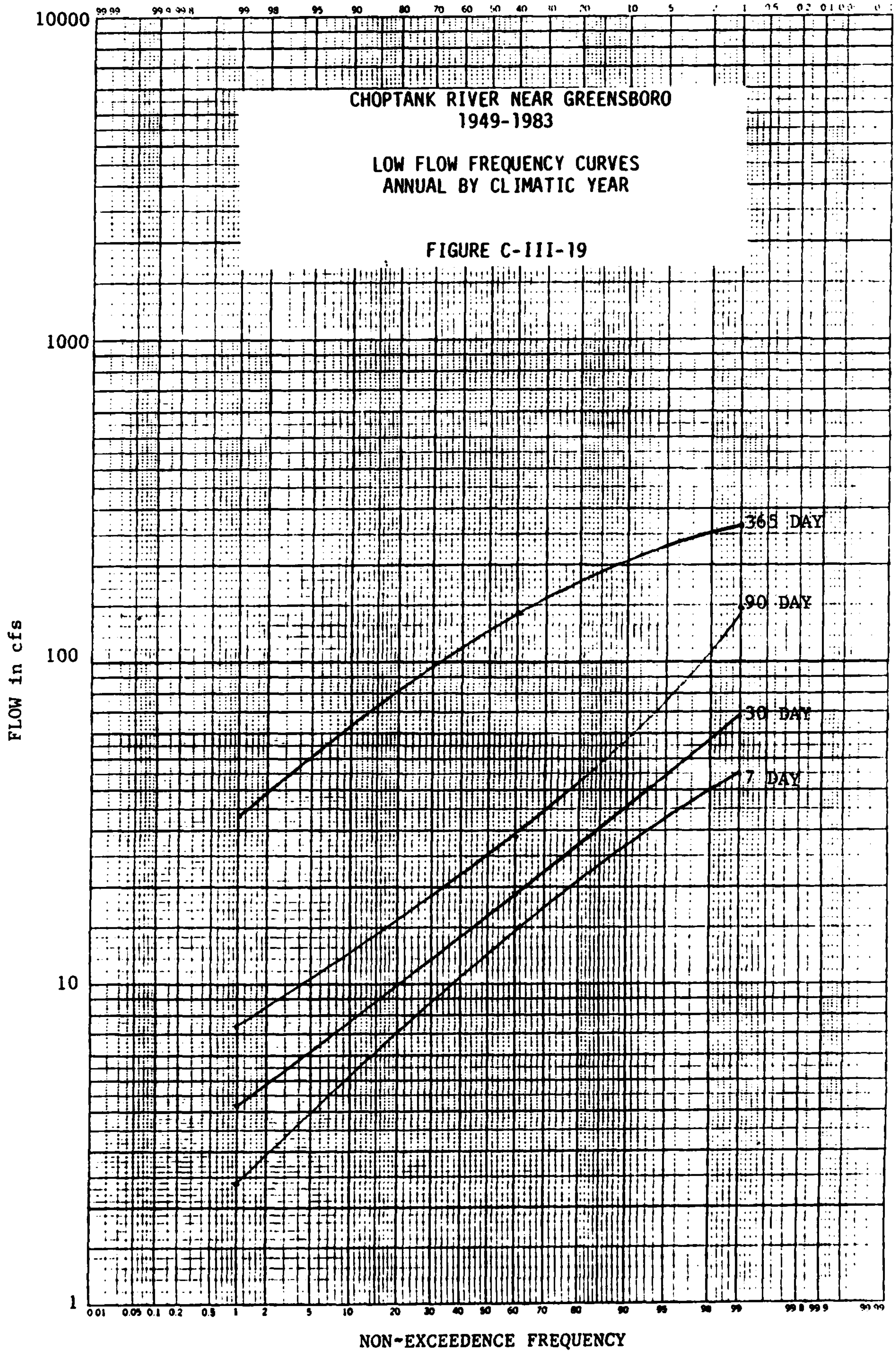


FIGURE C-III-18


CHOPTANK RIVER NEAR GREENSBORO
1949-1983
LOW FLOW FREQUENCY CURVES
ANNUAL BY CLIMATIC YEAR
FIGURE C-III-19
365 DAY
90 DAY
30 DAY
7 DAY
10000
1000
100
10
1
FLOW in cfs
NON-EXCEEDENCE FREQUENCY

HISTORICAL HYDROGRAPH NANTICOKE RIVER NEAR BRIDGEVILLE
ANNUAL BY CLIMATIC YEAR

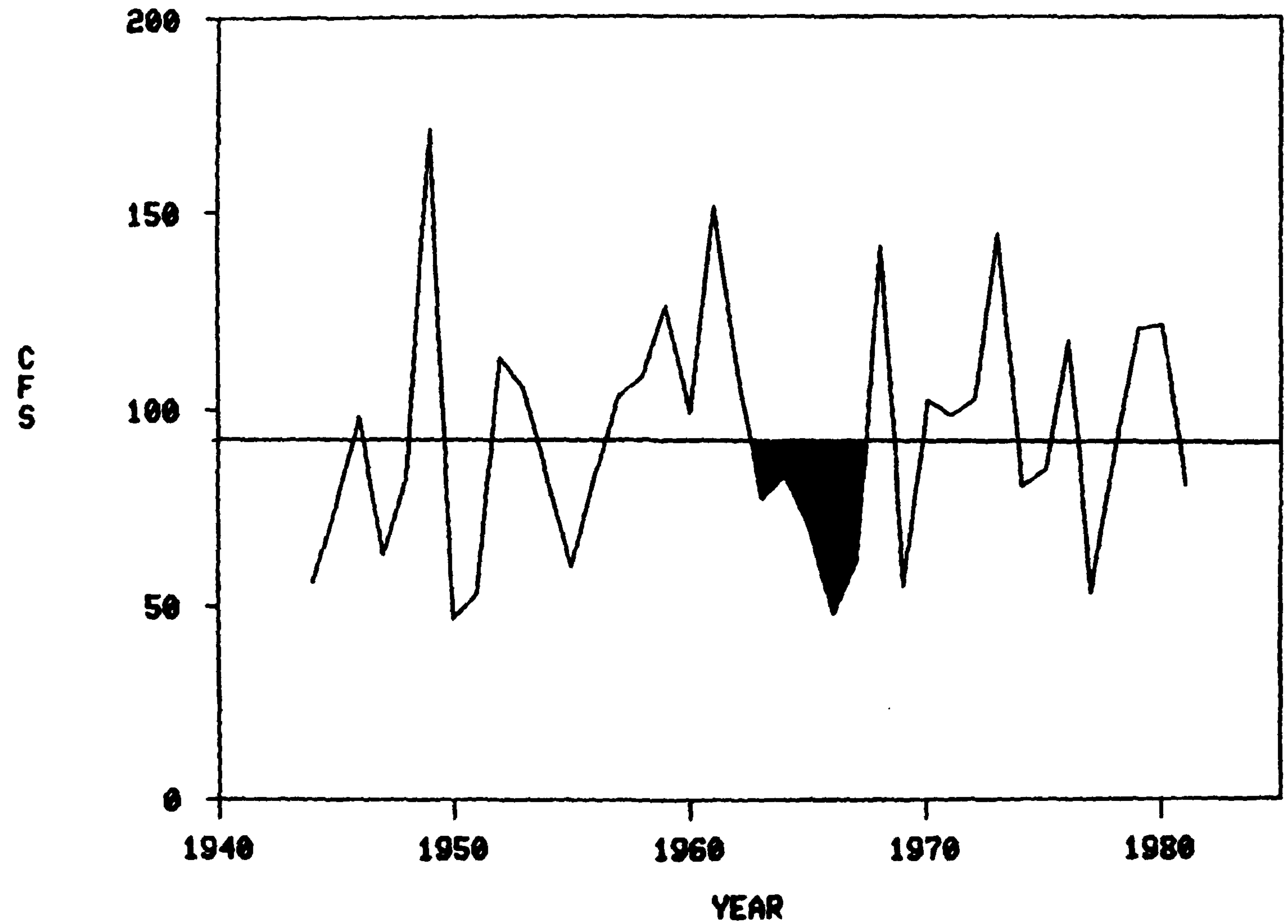
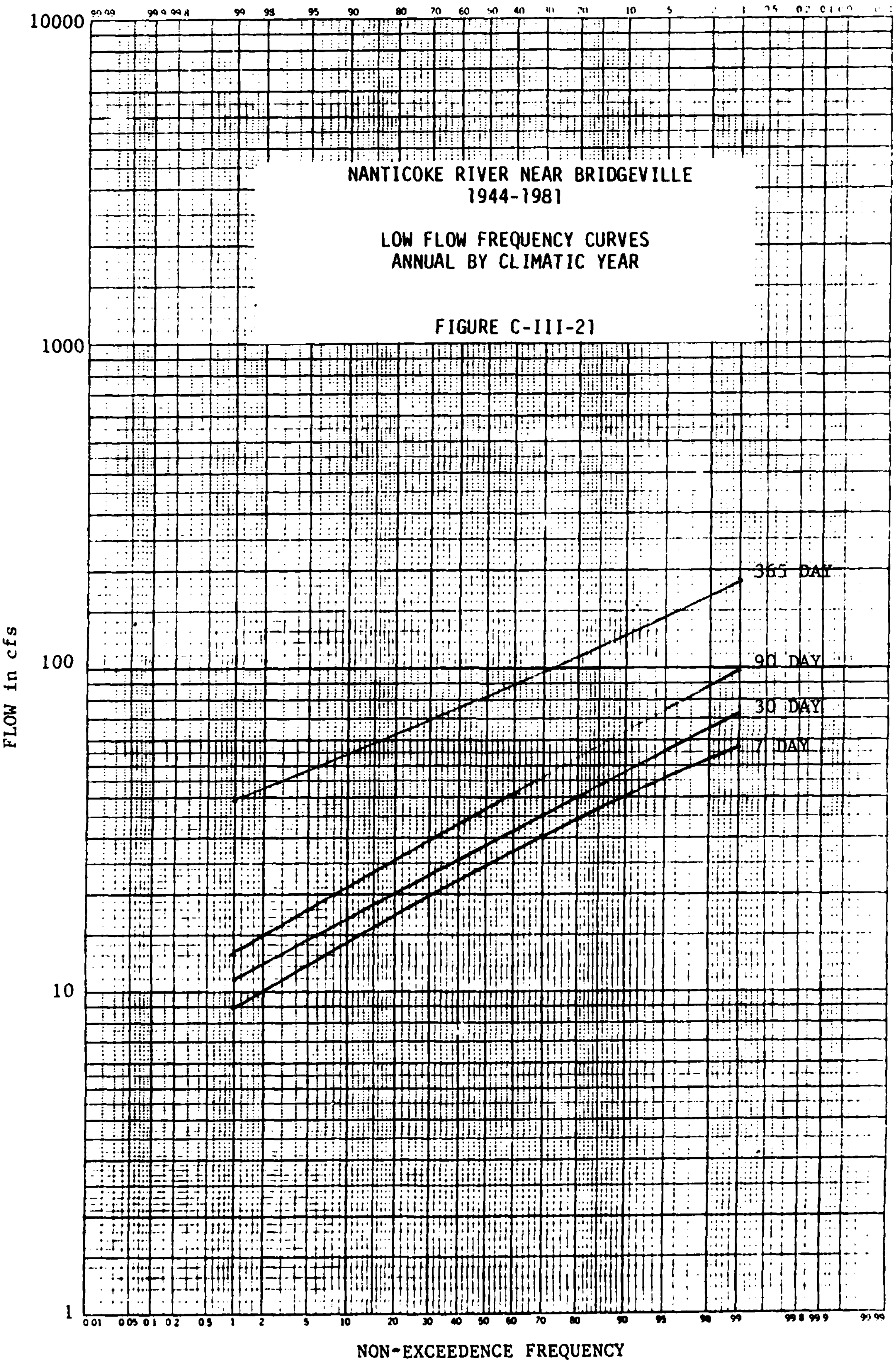


FIGURE C-III-20


NANTICOKE RIVER NEAR BRIDGEVILLE
1944-1981
LOW FLOW FREQUENCY CURVES
ANNUAL BY CLIMATIC YEAR
FIGURE C-III-21
365 DAY
90 DAY
30 DAY
7 DAY
FLOW in cfs
10000
1000
100
10
1
NON-EXCEEDENCE FREQUENCY

HISTORICAL HYDROGRAPH POCOMOKE RIVER NEAR WILLARDS
ANNUAL BY CLIMATIC YEAR

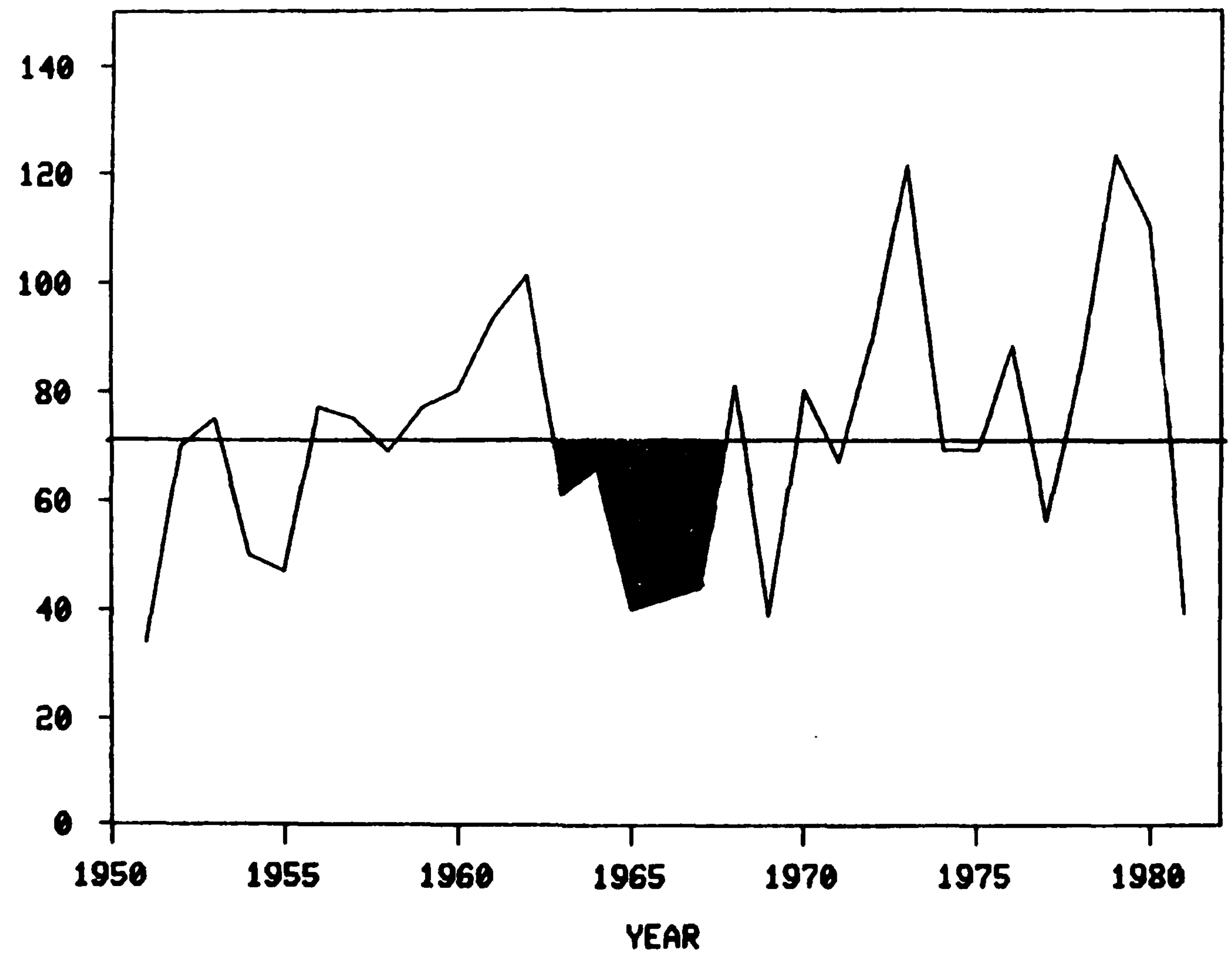


FIGURE C-III-22

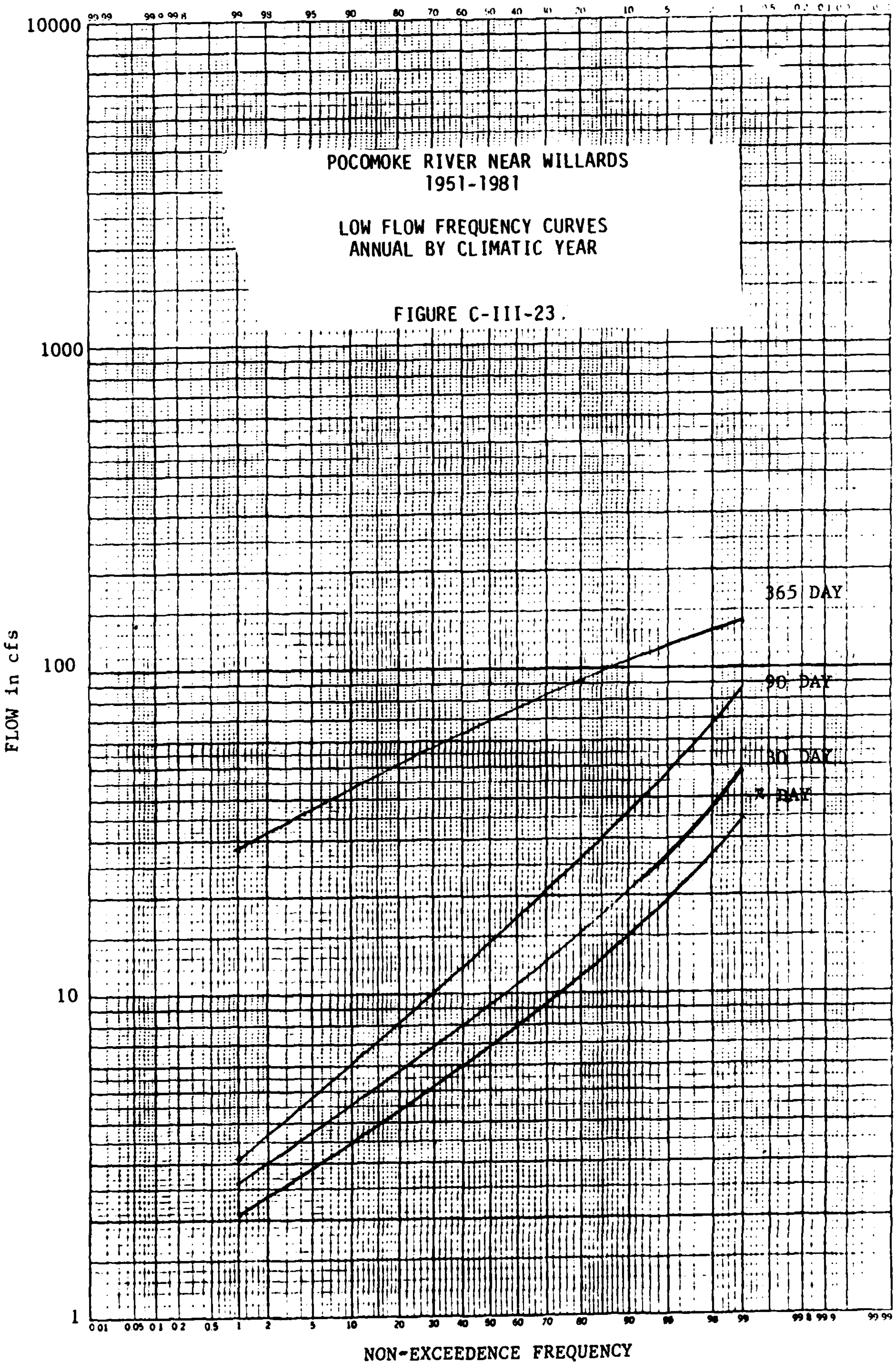


FIGURE C-III-23.

TABLE C-III-2

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
JAMES RIVER AT CARTERSVILLE

	7-Day		30-Day		90-Day		365-Day	
Rank	Flow (cfs)	CY	Flow (cfs)	CY	Flow (cfs)	CY	Flow (cfs)	CY
1	386	1967	487	1931	575	1931	2070	1931
2	394	1931	591	1967	732	1967	3550	1942
3	446	1933	618	1933	796	1964	3560	1966
4	558	1955	686	1955	907	1933	3820	1969
5	563	1965	693	1971	947	1942	4290	1964
6	583	1966	709	1942	972	1965	4350	1926
7	592	1969	721	1969	982	1926	4380	1940
8	602	1964	743	1965	1010	1978	4460	1956
9	626	1957	752	1964	1040	1954	4520	1954
10	663	1942	765	1966	1110	1932	5030	1965

Compiled from WATSTORE Data, USGS.

TABLE C-III-3

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
MATTAPONI RIVER NEAR BEULAHVILLE

	7-Day		30-Day		90-Day		365-Day	
Rank	Flow (cfs)	CY	Flow (cfs)	CY	Flow (cfs)	CY	Flow (cfs)	CY
1	8	1967	12	1955	32	1955	214	1955
2	10	1955	15	1967	34	1981	265	1981
3	12	1969	17	1981	37	1967	270	1966
4	13	1981	19	1978	39	1944	285	1969
5	14	1978	21	1969	40	1964	339	1968
6	20	1944	26	1944	45	1978	353	1944
7	20	1971	31	1964	49	1969	356	1967
8	21	1964	31	1971	49	1971	398	1954
9	23	1945	40	1958	71	1954	416	1945
10	27	1954	43	1954	76	1968	422	1964

Compiled from WATSTORE Data, USGS

TABLE C-III-4

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
RAPPAHANNOCK RIVER NEAR FREDERICKSBURG

Rank	7-Day Flow (cfs)	7-Day CY	30-Day Flow (cfs)	30-Day CY	90-Day Flow (cfs)	90-Day CY	365-Day Flow (cfs)	365-Day CY
1	8	1931	14	1931	27	1931	328	1931
2	10	1967	26	1955	69	1964	671	1966
3	14	1955	46	1967	79	1955	764	1932
4	24	1933	53	1958	125	1932	896	1969
5	36	1958	57	1933	134	1944	905	1955
6	42	1965	59	1964	136	1958	946	1954
7	43	1964	71	1954	139	1967	967	1964
8	55	1954	73	1965	143	1954	985	1942
9	66	1966	92	1932	148	1933	1040	1926
10	72	1932	102	1944	192	1942	1070	1981

Compiled from WATSTORE Data, USGS.

TABLE C-III-5

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
POTOMAC RIVER AT POINT OF ROCKS

Rank	7-Day Flow (cfs)	7-Day CY	30-Day Flow (cfs)	30-Day CY	90-Day Flow (cfs)	90-Day CY	365-Day Flow (cfs)	365-Day CY
1	593	1967	703	1931	762	1931	2440	1931
2	661	1931	829	1967	1040	1967	4620	1966
3	695	1965	936	1933	1160	1964	5030	1969
4	739	1924	941	1926	1170	1923	5180	1942
5	749	1933	942	1932	1220	1932	5210	1901
6	822	1966	958	1924	1220	1933	5650	1923
7	833	1960	961	1965	1280	1966	5990	1896
8	841	1915	965	1964	1290	1958	6040	1948
9	841	1918	974	1958	1320	1896	6140	1947
10	859	1926	982	1923	1350	1905	6200	1954

Compiled from WATSTORE Data, USGS.

TABLE C-III-6

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
PATUXENT RIVER NEAR LAUREL

Rank	7-Day Flow (cfs)	7-Day CY	30-Day Flow (cfs)	30-Day CY	90-Day Flow (cfs)	90-Day CY	365-Day Flow (cfs)	365-Day CY
1	4	1967	4	1967	6	1967	16	1966
2	6	1957	8	1968	8	1966	19	1970
3	7	1965	8	1965	8	1968	22	1967
4	8	1968	8	1966	9	1965	23	1969
5	8	1966	9	1960	10	1960	23	1955
6	8	1970	10	1957	11	1962	25	1963
7	8	1974	10	1963	11	1963	26	1965
8	8	1960	10	1964	11	1964	29	1982
9	9	1962	11	1970	12	1970	29	1960
10	9	1963	11	1959	12	1971	31	1964

Compiled from WATSTORE Data, USGS.

TABLE C-III-7

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
PATAPSCO RIVER AT HOLLOFIELD

Rank	7-Day Flow (cfs)	7-Day CY	30-Day Flow (cfs)	30-Day CY	90-Day Flow (cfs)	90-Day CY	365-Day Flow (cfs)	365-Day CY
1	11	1964	18	1964	23	1964	63	1966
2	15	1967	18	1967	23	1967	81	1967
3	16	1963	20	1963	28	1965	82	1964
4	17	1958	22	1965	29	1955	84	1970
5	19	1965	22	1958	34	1963	86	1960
6	20	1955	23	1955	34	1966	88	1965
7	22	1966	26	1971	36	1971	93	1969
8	23	1978	27	1978	36	1958	94	1963
9	23	1956	28	1956	43	1981	105	1955
10	25	1960	29	1966	44	1962	119	1962

Compiled from WATSTORE Data, USGS.

TABLE C-III-8

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
SUSQUEHANNA RIVER AT HARRISBURG

Rank	7-Day Flow (cfs)	7-Day CY	30-Day Flow (cfs)	30-Day CY	90-Day Flow (cfs)	90-Day CY	365-Day Flow (cfs)	365-Day CY
1	1790	1965	2060	1965	2290	1965	13,500	1931
2	1990	1933	2160	1931	2660	1931	17,500	1940
3	2010	1931	2290	1964	3110	1964	19,400	1965
4	2050	1940	2340	1933	3610	1966	22,600	1966
5	2160	1964	2640	1940	3640	1963	23,600	1967
6	2380	1967	2650	1901	3780	1954	23,800	1901
7	2430	1901	2770	1942	3830	1967	23,900	1942
8	2470	1942	3000	1967	3970	1910	24,700	1911
9	2580	1960	3010	1932	4000	1940	26,100	1924
10	2640	1966	3040	1944	4030	1932	26,100	1926

Compiled from WATSTORE Data, USGS.

TABLE C-III-9

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
BIG ELK CREEK AT ELK MILLS

Rank	7-Day Flow (cfs)	7-Day CY	30-Day Flow (cfs)	30-Day CY	90-Day Flow (cfs)	90-Day CY	365-Day Flow (cfs)	365-Day CY
1	5	1967	6	1967	10	1964	35	1966
2	6	1964	8	1964	11	1967	37	1955
3	7	1933	10	1933	15	1933	37	1964
4	10	1965	11	1965	15	1942	42	1942
5	10	1955	12	1958	16	1965	43	1965
6	10	1956	13	1966	16	1966	43	1967
7	10	1958	13	1945	17	1955	44	1969
8	11	1966	13	1956	19	1958	44	1981
9	11	1945	14	1942	21	1981	46	1970
10	12	1942	15	1955	21	1945	49	1945

Compiled from WATSTORE Data, USGS.

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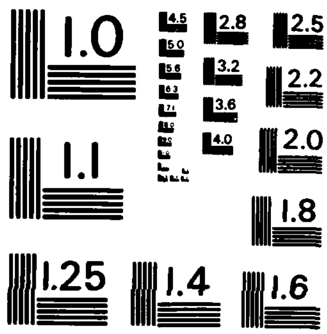


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE C-III-10

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
CHOPTANK RIVER NEAR GREENSBORO

Rank	7-Day Flow (cfs)	7-Day CY	30-Day Flow (cfs)	30-Day CY	90-Day Flow (cfs)	90-Day CY	365-Day Flow (cfs)	365-Day CY
1	2	1967	4	1967	10	1958	30	1966
2	4	1978	6	1978	10	1967	58	1977
3	6	1966	7	1958	11	1966	66	1950
4	6	1958	9	1966	13	1978	68	1955
5	7	1964	9	1965	13	1965	74	1969
6	7	1965	10	1964	14	1969	76	1965
7	7	1950	10	1977	14	1950	85	1956
8	8	1972	11	1950	14	1963	90	1967
9	8	1977	11	1963	14	1964	92	1951
10	8	1969	11	1971	15	1971	96	1963

Compiled from WATSTORE Data, USGS.

TABLE C-III-11

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
NANTICOKE RIVER NEAR BRIDGEVILLE

Rank	7-Day Flow (cfs)	7-Day CY	30-Day Flow (cfs)	30-Day CY	90-Day Flow (cfs)	90-Day CY	365-Day Flow (cfs)	365-Day CY
1	8	1944	10	1944	12	1944	47	1950
2	13	1945	15	1945	19	1945	48	1966
3	14	1948	16	1978	19	1950	53	1977
4	15	1978	17	1950	20	1978	53	1951
5	16	1950	18	1958	21	1948	55	1969
6	17	1958	18	1977	23	1958	56	1944
7	17	1977	19	1948	24	1977	60	1955
8	18	1955	21	1955	25	1966	61	1967
9	20	1951	22	1967	28	1967	63	1947
10	21	1952	22	1951	28	1947	70	1965

Compiled from WATSTORE Data, USGS.

TABLE C-III-12

RECORDED LOW MEAN FLOWS FOR CONSECUTIVE DAYS IN CLIMATIC YEAR (CY)
ENDING 31 MARCH
POCOMOKE RIVER NEAR WILLARDS

Rank	7-Day Flow (cfs)	7-Day CY	30-Day Flow (cfs)	30-Day CY	90-Day Flow (cfs)	90-Day CY	365-Day Flow (cfs)	365-Day CY
1	3	1958	3	1965	4	1958	34	1951
2	3	1965	4	1958	5	1965	39	1969
3	3	1964	4	1969	5	1969	39	1981
4	3	1969	4	1981	6	1963	40	1965
5	3	1963	5	1963	6	1964	42	1966
6	4	1967	5	1967	6	1981	44	1967
7	4	1951	5	1964	7	1967	47	1955
8	4	1981	6	1971	10	1978	50	1954
9	5	1971	7	1978	11	1955	56	1977
10	5	1955	7	1955	11	1966	61	1963

Compiled from WATSTORE Data, USGS.

CHAPTER IV

STREAMFLOW CHARACTERISTICS AT MODEL INFLOW POINTS

The previous discussions have all dealt with the Chesapeake Bay Drainage Basin as described by the gages located on the streams and rivers tributary to it. In this chapter, however, the hydrology of the Bay basin will be discussed in the context of the 21 inflow points used in the Chesapeake Bay Model Low Freshwater Inflow Test.

In Figure C-IV-1 the locations of the 21 inflow points used for the model test are shown along with the drainage areas for the inflow points. The methodology of translating the gaged streamflows to model inflows was based on a linear comparison between the gaged drainage areas and the drainage areas of the inflow points. The characteristics of the gaged areas were determined, and those gaged flows were used in computing the flows for ungaged areas with similar characteristics. Table C-IV-1 lists the total drainage area of each inflow point, the portion of the area that is gaged, and the ratio of ungaged area to gaged area. Table C-IV-2 lists the gages used for each of the 21 inflow points.

As previously stated, the Low Freshwater Inflow Test included both drought and average flow conditions. For the Base Drought conditions, the records from the 1964-1966 drought were modified to reflect the effects of three major dams: Gathright on the James River, Bloomington on the Potomac River, and Raystown on the Susquehanna River. The future flows were computed by subtracting from the Base Drought inflow the increase in consumptive losses expected by the year 2020.

The Base Average inflows did not include any of these dams; however, there were modifications due to waste treatment plants and diversions of water. The Future Average flows were the Base Average flows depressed by the year 2020 consumptive losses.

The first analysis to be discussed is the flow-duration evaluation. A flow-duration curve shows the percent of time particular flows are equalled or exceeded doing a particular period of time. It is prepared by taking the historical flows (whether they be average daily, weekly, yearly, etc.) and dividing them into classes. A particular flow can then be placed into a certain category.

In this analysis, the data used are the computed monthly flows for each inflow point of the Chesapeake Bay Model. (The volume of data depends on the length of record of the gages used in the computations.)

Figures C-IV-2 through C-IV-22 (and the accompanying tables) present the monthly, seasonal, and yearly average flows, and those occurring 5, 80, 90, and 95 percent of the time for those same periods. (Note that in the table accompanying Figure C-IV-2 that the 95 percent flow for January is 190 cfs.)

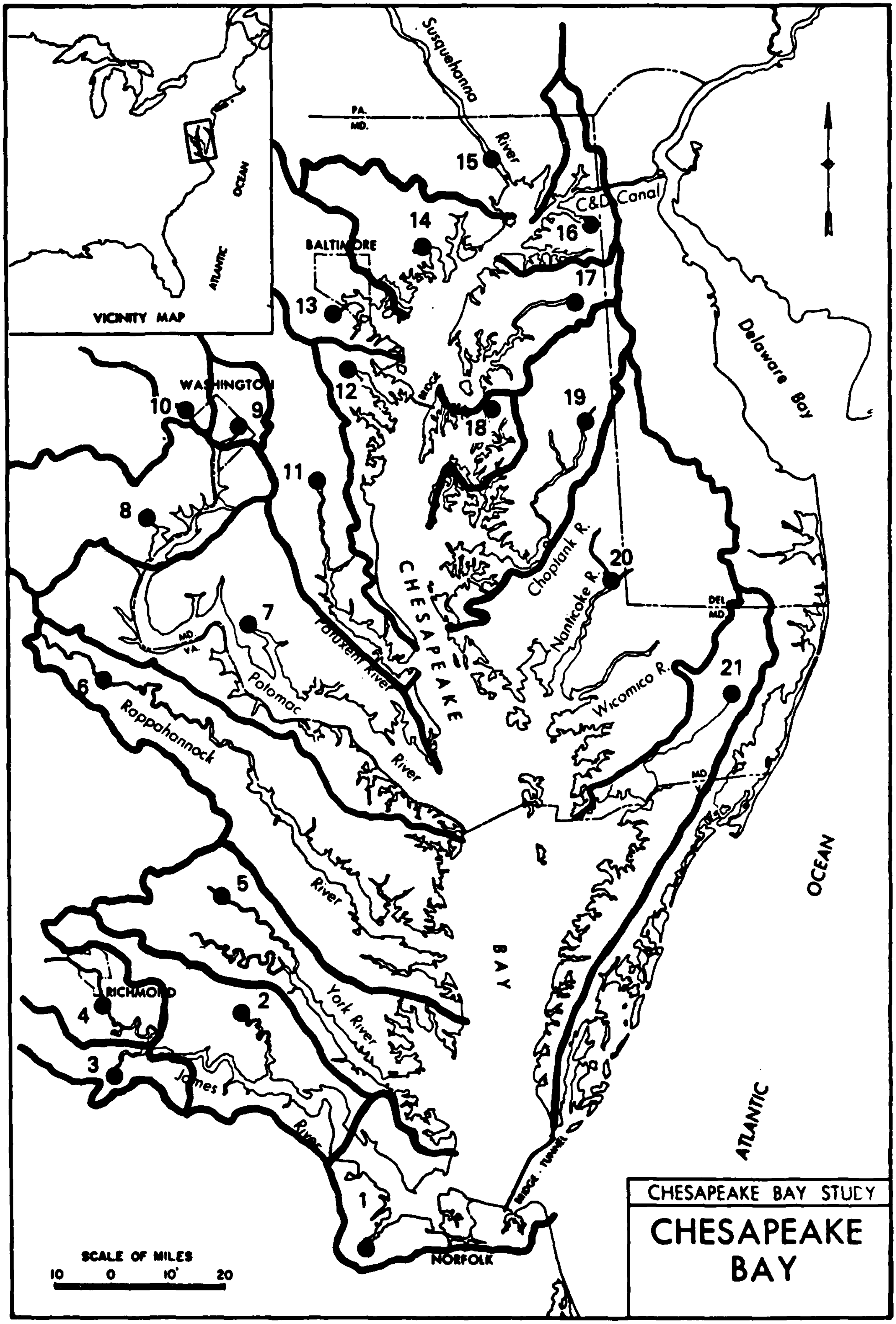


FIGURE C-IV-1 FRESHWATER INFLOW POINTS AND DRAINAGE AREAS

TABLE C-IV-1

TOTAL VS. GAGED DRAINAGE AREAS
Square Miles

Inflow Point	Total Drainage Area	Gaged Drainage Area	Ratio Total Area to Gaged Area
1	696	248	2.81
2	784	248	3.16
3	1671	1583	1.06
4	7036	7038	1.00
5	2857	2022	1.41
6	2885	1755	1.64
7	1364	76	17.95
8	1000	222	4.50
9	247	122	2.02
10	11,606	11,560	1.00
11	875	215	4.07
12	294	19	15.47
13	581	325	1.79
14	693	171	4.05
15	27,510	26,019	1.06
16	354	88	4.02
17	488	35	13.94
18	173	119	1.5
19	746	119	6.27
20	1400	204	6.86
21	900	105	8.57

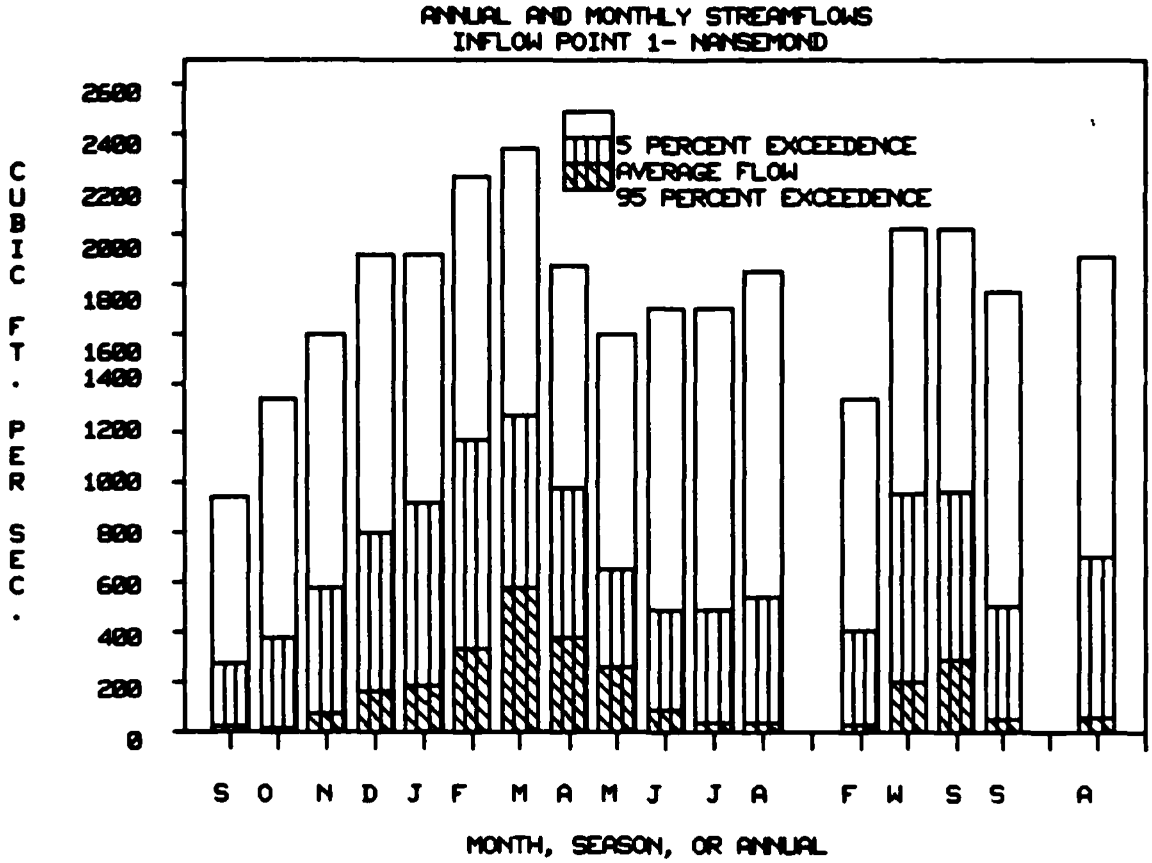
TABLE C-IV-2

GAGE STATIONS USED FOR INFLOW POINTS

Inflow Point	Drainage Area (mi^2)	Gage Location	Drainage Area of Gage (mi^2)
1	696	Chickahominy River near Providence Forge, Va.	248
2	784	Chickahominy River near Providence Forge, Va.	248
3	1671	Chickahominy River near Providence Forge, Va.	248
		Appomattox River near Petersburg	1,335
4	7036	James River & Kanawha Canal near Richmond, Va.	NA
		James River near Richmond, Va.	6,757
		Falling Creek near Chesterfield, Va.	33
		Chickahominy River near Providence Forge, Va.	248
5	2857	Dragon Swamp near Church View, Va.	86
		Beaverdam Swamp near Ark, Va.	7
		Pamunkey River near Hanover, Va.	1,072
		Mattaponi River near Beulahville, Va.	619
		Chickahominy River near Providence Forge, Va.	248
6	2885	Rappahannock River near Fredericksburg, Va.	1,599
		Cat Point Creek near Montross, Va.	45
		Piscataway Creek near Tappahannock, Va.	28
		Dragon Swamp near Church View, Va.	86
7	1364	Mattawoman Creek near Pomonkey, Md.	58
		South Fork Quantico Creek near Independent Hill, Va.	8
		Chaptico Creek at Chaptico, Md.	11
8	1000	Cameron Run at Alexandria, Va.	34
		Henson Creek	17
		Accotink Creek near Annandale, Va.	24
		Bull Run near Manassas, Va.	148
9	247	N.E. Branch Anacostia River	73
		N.W. Branch Anacostia River	49
10	11,606	Potomac River near D.C.	11,560

TABLE C-IV-2 (cont'd)

Inflow Point	Drainage Area (mi^2)	Gage Location	Drainage Area of Gage (mi^2)
11	875	Patuxent River at Laurel, Md.	132
		Little Patuxent River at Guilford, Md.	38
		Western Branch near Largo, Md	30
		Cocktown Creek near Huntington, Md.	4
		Chaptico Creek at Chaptico, Md.	11
12	294	North River at Annapolis, Md.	8
		Chaptico Creek at Chaptico, Md.	11
13	581	Patapsco River at Hollofield, Md.	285
		East Br. Herbert Run	2
		Gwynns Falls at Villa/Nova, Md.	32
		Dead Run at Franklintown, Md.	6
14	693	Bynum Run at Bel Air, Md.	9
		Little Falls at Blue Mount, Md.	53
		Western Run at Western Run, Md.	60
		Little Gunpowder Falls	36
		Whitemarsh Run at White Marsh, Md.	8
		Stemmers Run at Rossville, Md.	42
		Brian Run at Stemmers Run, Md.	2
15	27,631	Northeast Creek at Leslie, Md.	24
		Susquehanna River at Marietta, Pa.	25,990
		Deer Creek at Rocks, Md.	94
16	331	Unicorn Br. near Millington, Md.	22
		Morgan Creek near Kennedysville, Md.	10
		Big Elk Creek at Big Elk, Md	53
17	488	Unicorn Br. near Millington, Md.	22
		Morgan Creek near Kennedysville, Md.	10
18	173	Choptank River near Greensboro, Md.	113
		Beauerdam Br. at Matthews, Md.	6
19	746	Choptank River near Greensboro, Md.	113
		Beaverdam Br. at Matthews, Md.	6
20	1400	Nassawango Creek near Snow Hill, Md.	45
		Nanticoke River near Bridgeville, Del.	75
		Trap Pond Outlet	
		Marshyhope Creek near Adamsville, Del.	44
		Faulkner Br. at Federalsburg, Md.	7
		Chickacomico River near Salem, Md.	15
21	900	Pocomoke River near Willards, Md.	650
		Nassawango Creek near Snow Hill, Md.	45

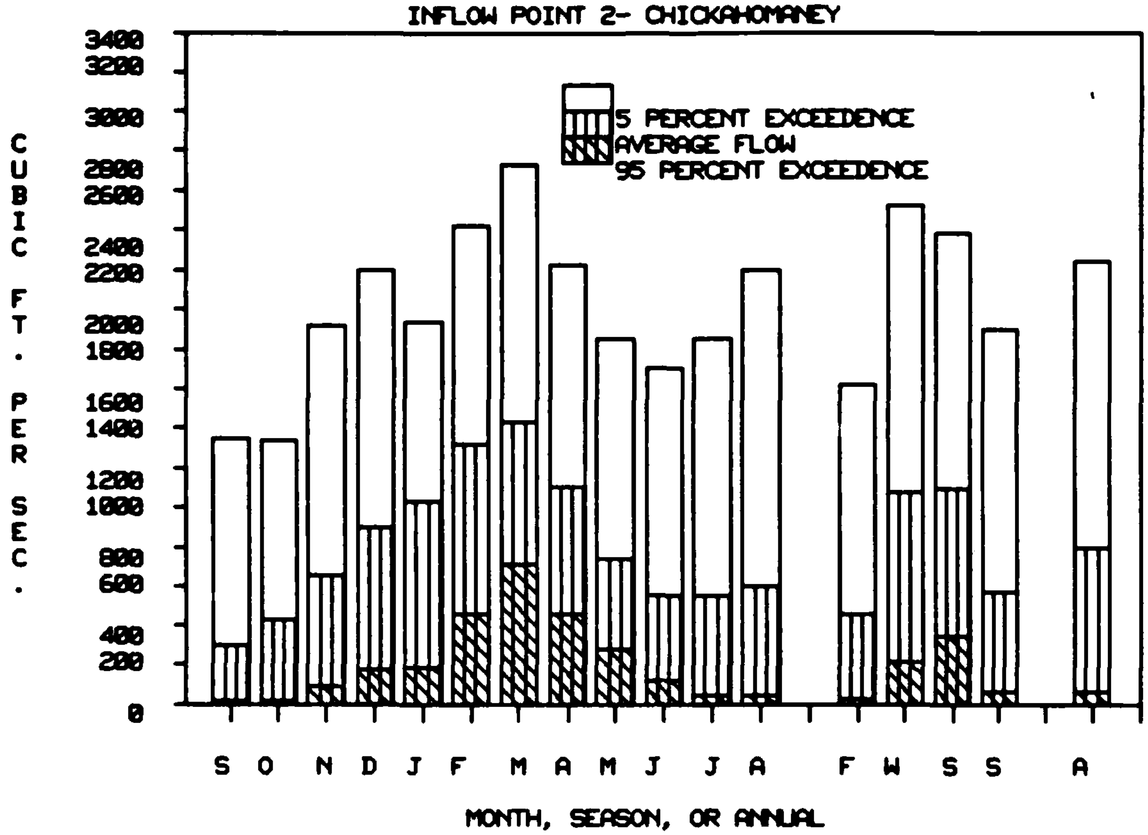


Month or Season	Average Flow cfs	5% cfs	Exceedence Percentag 80% cfs	90% cfs	95% cfs
September	270	940	90	50	20
October	380	1,340	70	40	10
November	580	1,600	200	150	70
December	800	1,920	380	210	160
January	920	1,920	480	320	190
February	1,170	2,230	700	610	330
March	1,270	2,340	840	680	580
April	980	1,870	540	430	380
May	650	1,600	330	280	260
June	490	1,700	170	100	90
July	490	1,700	90	70	40
August	540	1,850	70	50	40
Fall	410	1,340	110	50	30
Winter	960	2,020	490	330	200
Spring	970	2,020	460	360	290
Summer	510	1,770	100	70	50
Annual	710	1,910	200	100	60

Values have been rounded to three significant figures.

FIGURE C-IV-2

ANNUAL AND MONTHLY STREAMFLOWS
INFLOW POINT 2- CHICKAHOMANEY

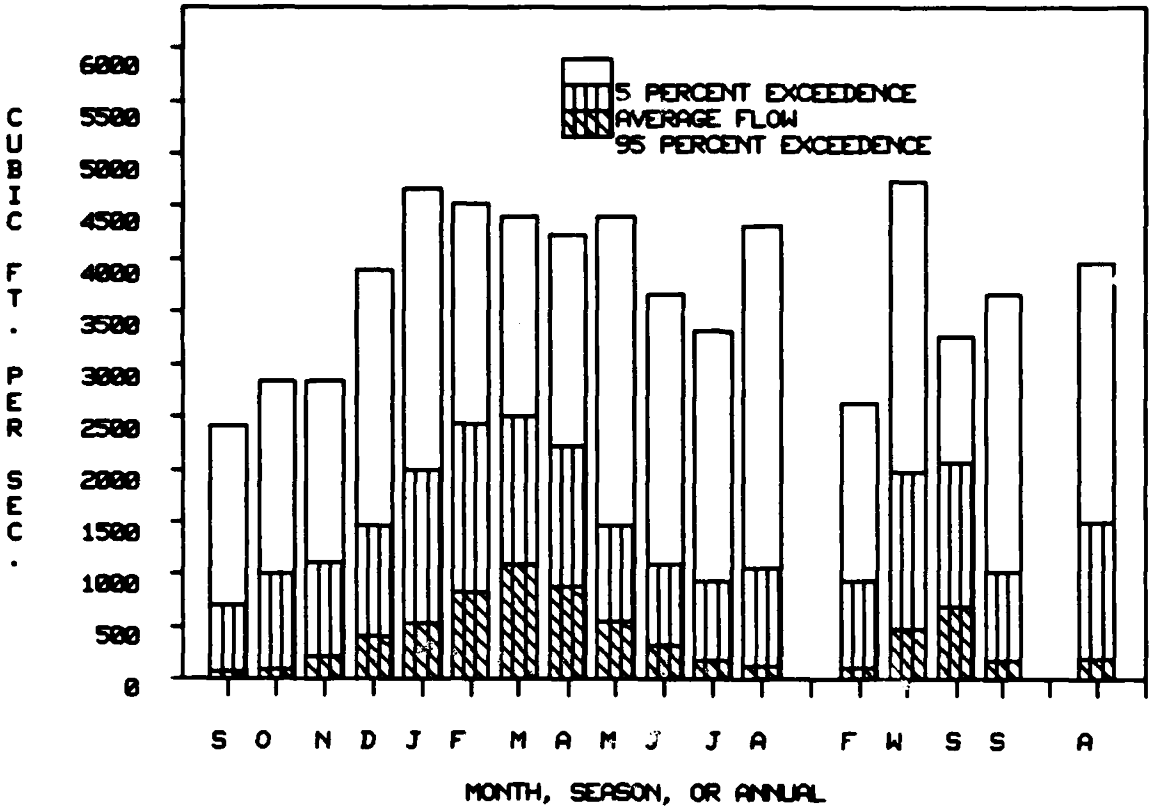


Month or Season	Average Flow cfs	Exceedence Percentage 5 % cfs	80 % cfs	90 % cfs	95 % cfs
September	300	1,350	90	60	20
October	430	1,340	70	40	20
November	650	1,920	220	150	90
December	900	2,200	410	310	180
January	1,030	1,940	520	410	190
February	1,320	2,420	810	610	460
March	1,430	2,730	940	810	710
April	1,100	2,230	590	520	460
May	740	1,850	390	320	280
June	550	1,700	200	130	120
July	550	1,850	120	70	50
August	600	2,200	80	60	50
Fall	460	1,620	120	60	30
Winter	1,080	2,520	570	410	220
Spring	1,090	2,390	550	430	340
Summer	570	1,900	130	70	60
Annual	800	2,240	220	120	70

Values have been rounded to three significant figures.

FIGURE C-IV-3

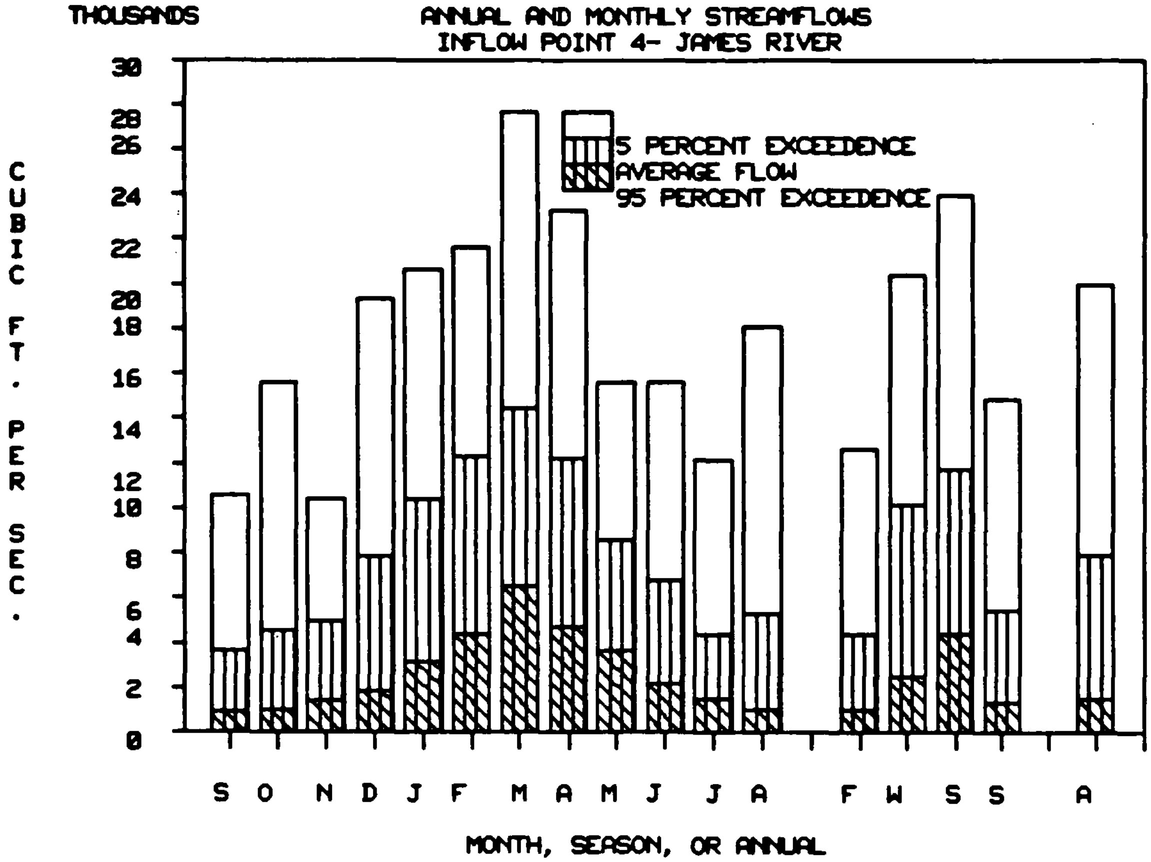
ANNUAL AND MONTHLY STREAMFLOWS
INFLOW POINT 3- APPOMATTOX



Month or Season	Average Flow cfs	5 % cfs	80 % cfs	90 % cfs	95 % cfs
		Exceedence Percentage			
September	700	2,420	220	120	70
October	1,000	2,830	260	130	90
November	1,110	2,830	410	250	210
December	1,460	3,890	700	490	410
January	2,000	4,670	1,090	650	520
February	2,430	4,530	1,390	1,050	830
March	2,490	4,410	1,560	1,270	1,100
April	2,220	4,220	1,540	1,090	890
May	1,470	4,400	780	620	540
June	1,080	3,670	470	370	310
July	940	3,320	310	210	170
August	1,050	4,320	230	170	120
Fall	940	2,620	280	170	100
Winter	1,960	4,740	940	650	480
Spring	2,060	3,250	2,080	840	690
Summer	1,020	3,670	340	210	170
Annual	1,500	3,970	510	310	190

Values have been rounded to three significant figures.

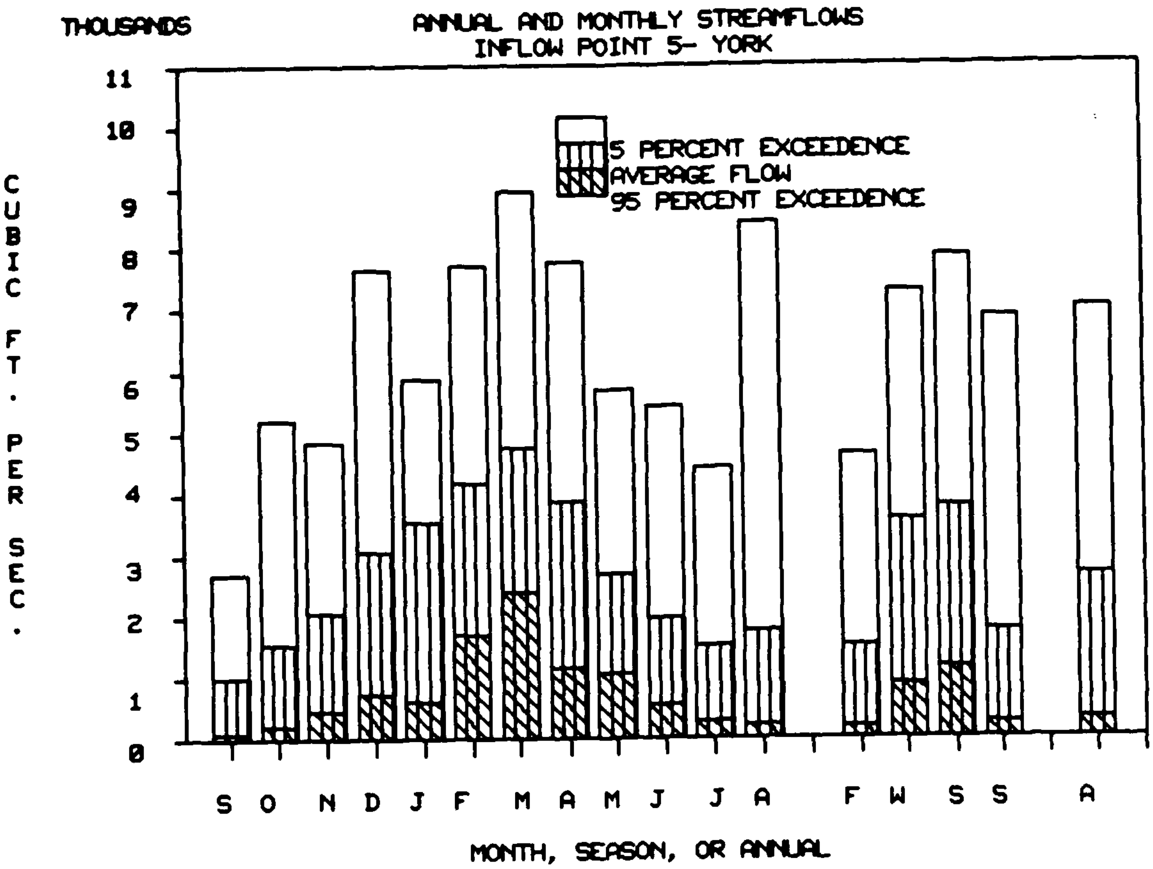
FIGURE C-IV-4



Month or Season	Average Flow cfs	5 % cfs	80 % cfs	90 % cfs	95 % cfs
			Exceedence Percentage		
September	3,620	10,600	1,530	1,090	890
October	4,580	15,600	1,720	1,250	980
November	4,980	10,400	2,060	1,640	1,370
December	7,840	19,300	3,250	2,410	1,840
January	10,400	20,600	6,270	4,180	3,190
February	12,300	21,600	6,910	5,380	4,430
March	14,400	27,700	8,800	7,570	6,500
April	12,200	23,300	7,330	5,620	4,680
May	8,600	15,600	5,000	4,170	3,620
June	6,710	15,600	3,120	2,390	2,120
July	4,390	12,100	2,100	1,700	1,460
August	5,280	18,100	1,700	1,210	940
Fall	4,400	12,600	1,720	1,310	1,030
Winter	10,200	20,400	5,140	3,380	2,520
Spring	11,700	23,900	6,570	5,180	4,360
Summer	5,460	14,900	2,220	1,680	1,290
Annual	7,940	20,000	2,710	1,860	1,480

Values have been rounded to three significant figures.

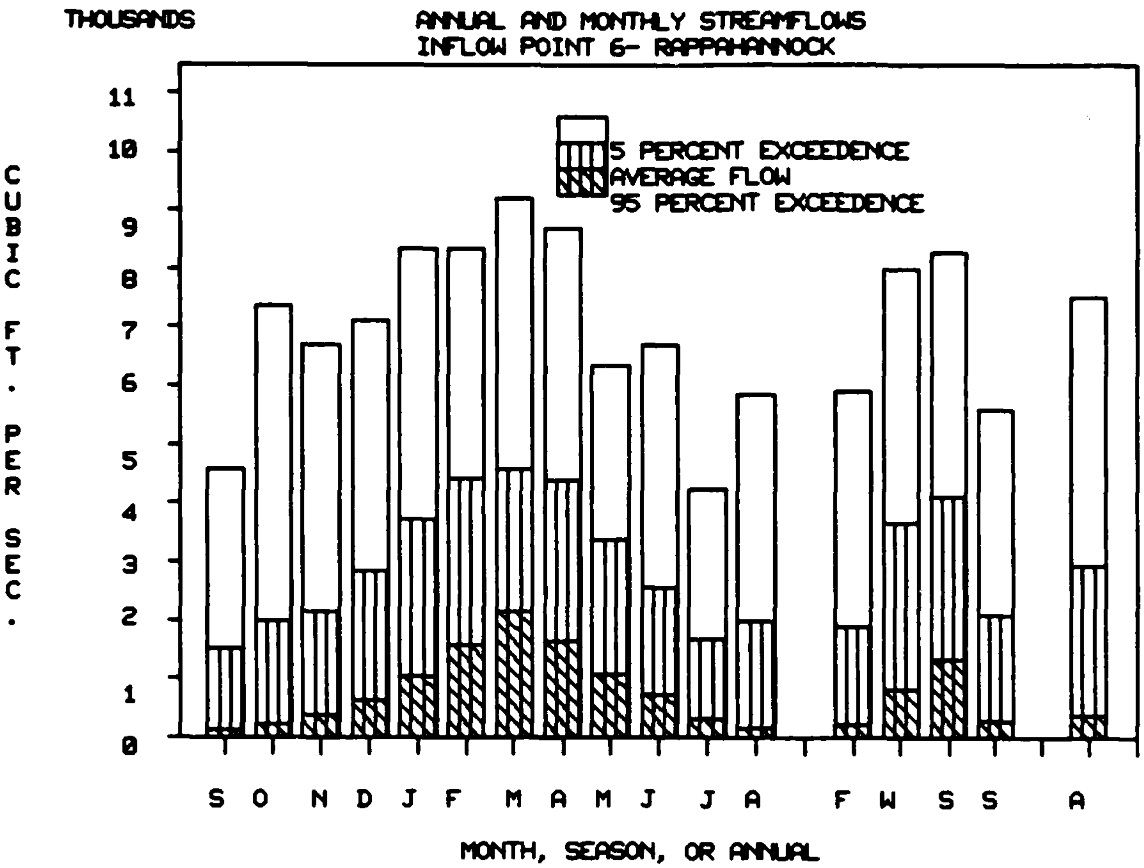
FIGURE C-IV-5



Month or Season	Average Flow cfs	Exceedence Percentage 5 % cfs	80 % cfs	90 % cfs	95 % cfs
September	990	2,700	320	160	110
October	1,540	5,210	320	230	190
November	2,070	4,850	920	640	460
December	3,050	7,640	1,530	1,030	720
January	3,550	5,880	1,850	1,050	600
February	4,170	7,700	2,240	1,900	1,700
March	4,760	8,940	3,180	2,700	2,400
April	3,860	7,760	2,200	1,600	1,150
May	2,700	5,700	1,340	1,140	1,040
June	1,970	5,410	760	580	540
July	1,500	4,410	470	340	280
August	1,760	8,410	440	230	190
Fall	1,530	4,640	470	260	180
Winter	3,590	7,290	1,820	1,360	880
Spring	3,770	7,850	2,110	1,380	1,140
Summer	1,750	6,860	590	370	250
Annual	2,660	7,020	880	520	290

Values have been rounded to three significant figures.

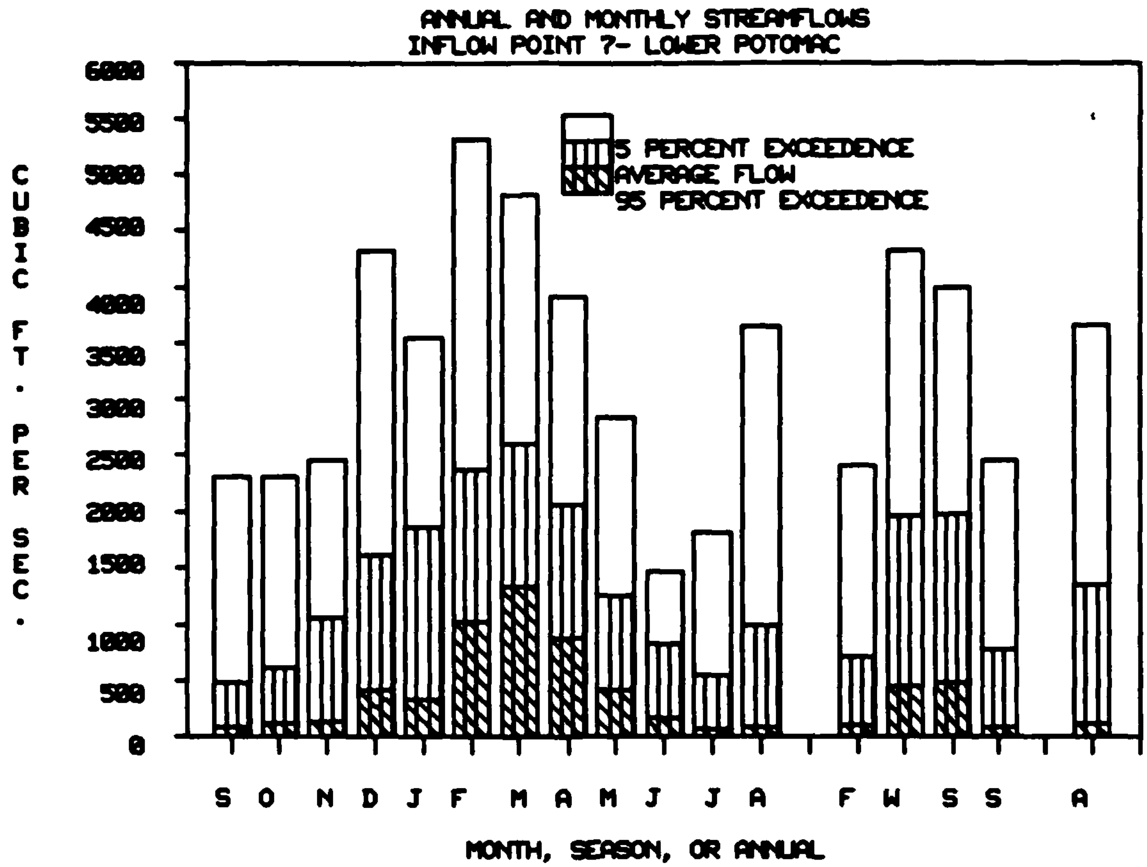
FIGURE C-IV-6



Month or Season	Average Flow cfs	5% cfs	Exceedence Percentage 80% cfs	90% cfs	95% cfs
September	1,540	4,570	380	260	130
October	1,980	7,380	500	290	210
November	2,170	6,710	880	560	360
December	2,840	7,130	1,200	860	630
January	3,730	8,360	2,070	1,450	1,040
February	4,410	8,360	2,410	2,080	1,570
March	4,580	9,210	2,840	2,530	2,170
April	4,400	8,710	2,230	1,850	1,640
May	3,380	6,360	1,590	1,260	1,070
June	2,560	6,710	1,080	870	750
July	1,700	4,240	730	480	300
August	2,010	5,840	540	240	160
Fall	1,900	5,900	500	320	220
Winter	3,660	8,000	1,950	1,180	830
Spring	4,120	8,290	2,140	1,670	1,340
Summer	2,090	5,580	780	520	290
Annual	2,940	7,550	1,000	600	380

Values have been rounded to three significant figures.

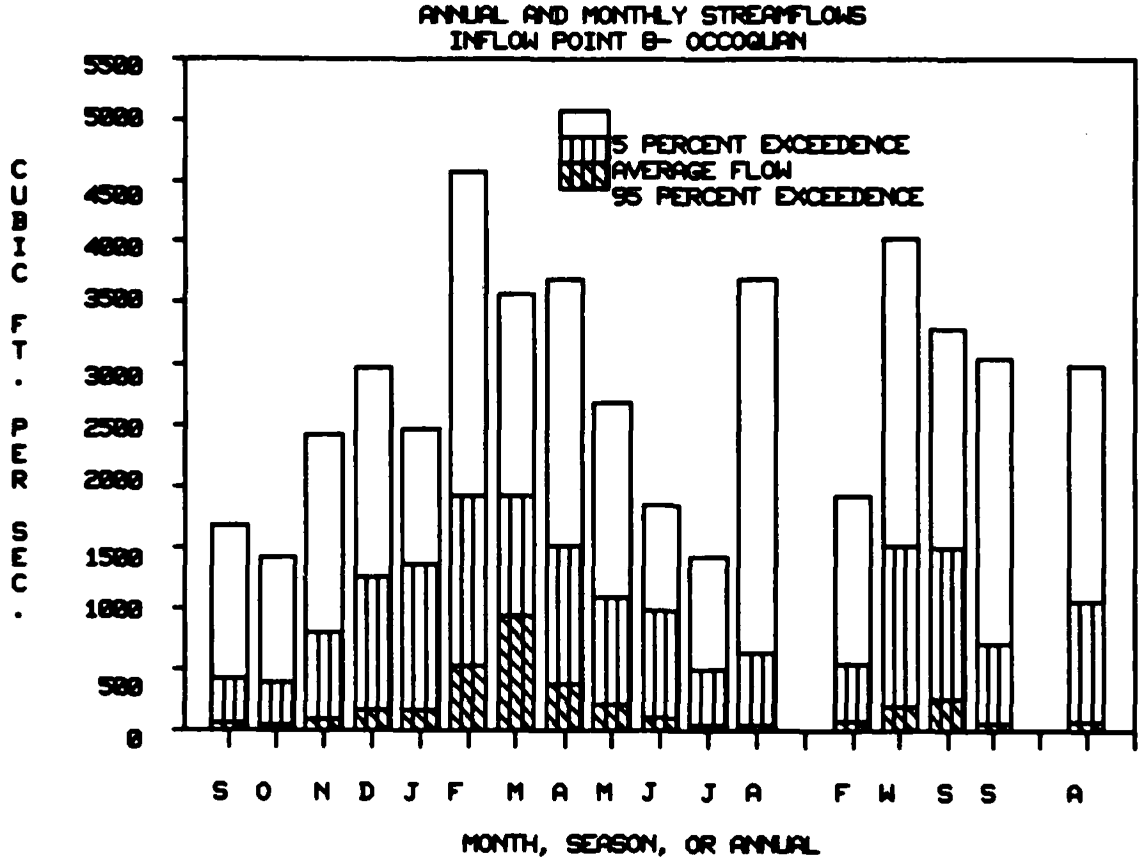
FIGURE C-IV-7



Month or Season	Average Flow cfs	Exceedence Percentage 5 % cfs	80 % cfs	90 % cfs	95 % cfs
September	480	2,320	120	100	80
October	600	2,320	140	120	110
November	1,060	2,460	380	290	130
December	1,620	4,320	760	490	420
January	1,870	3,550	960	570	340
February	2,380	5,320	1,310	1,120	1,030
March	2,610	4,820	1,740	1,550	1,340
April	2,070	3,910	1,120	940	870
May	1,250	2,830	520	440	410
June	820	1,470	270	210	170
July	550	1,820	160	90	70
August	980	3,650	190	160	90
Fall	710	2,410	140	120	100
Winter	1,960	4,320	980	770	450
Spring	1,980	3,990	1,010	650	480
Summer	780	2,460	200	150	90
Annual	1,360	3,670	300	170	120

Values have been rounded to three significant figures.

FIGURE C-IV-8



Month or Season	Average Flow cfs	5% cfs	80% cfs	90% cfs	95% cfs
			Exceedence Percentage		
September	420	1,680	90	80	60
October	390	1,420	90	70	50
November	800	2,420	200	130	90
December	1,260	2,960	410	210	170
January	1,370	2,460	810	460	170
February	1,910	4,570	1,020	720	530
March	1,910	3,570	1,270	1,050	930
April	1,510	3,690	720	430	370
May	1,080	2,680	320	230	210
June	980	1,850	190	140	110
July	500	1,420	140	70	40
August	640	3,690	80	60	50
Fall	540	1,910	120	80	70
Winter	1,510	4,020	670	390	200
Spring	1,500	3,280	680	390	250
Summer	710	3,040	150	80	60
Annual	1,060	2,970	220	130	80

Values have been rounded to three significant figures.

FIGURE C-IV-9

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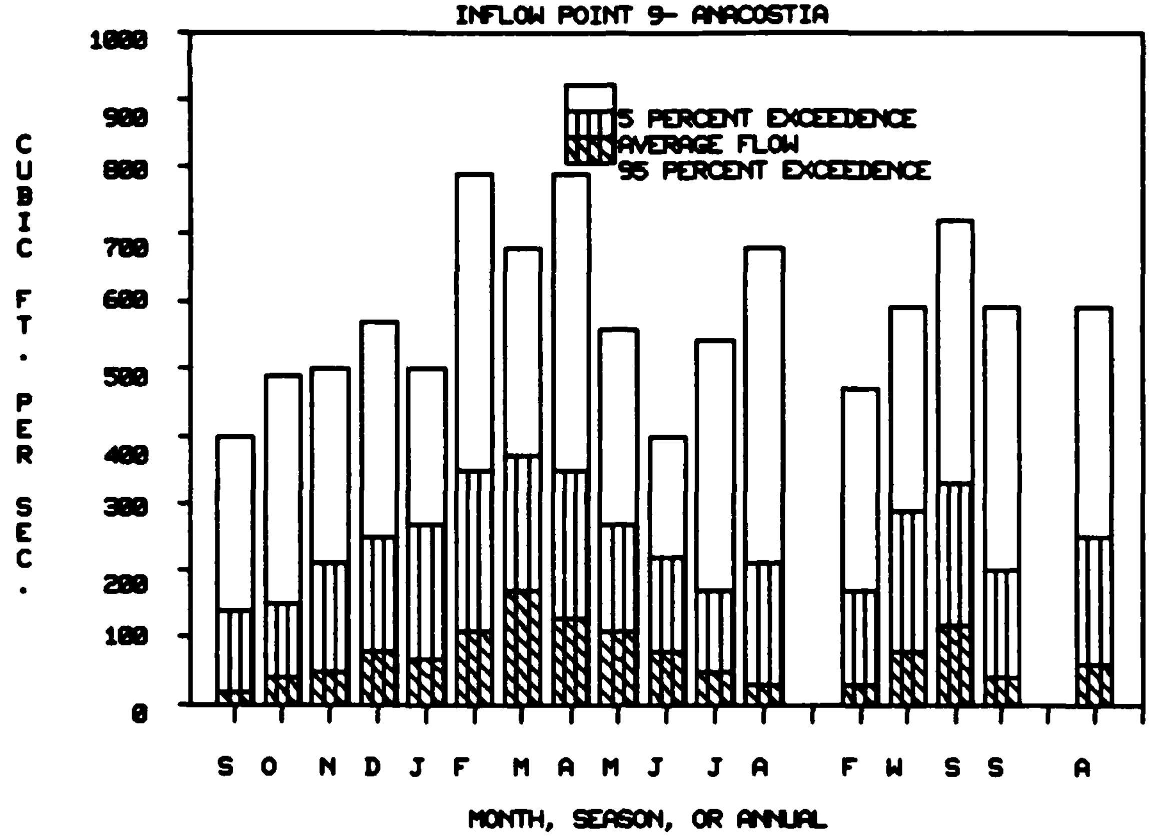
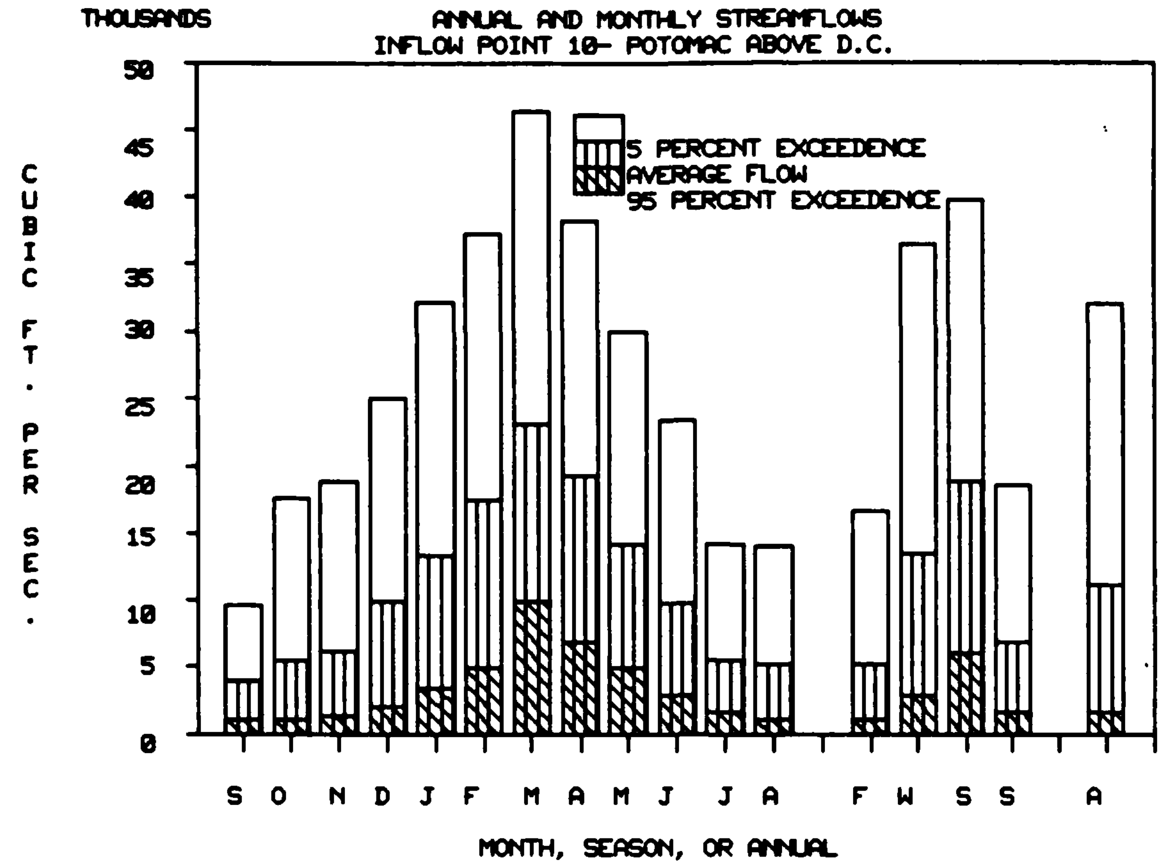
ANNUAL AND MONTHLY STREAMFLOWS
INFLOW POINT 9- ANACOSTIA



Month or Season	Average Flow cfs	Exceedence Percentage 5 % cfs	80 % cfs	90% cfs	95% cfs
September	140	400	60	50	20
October	150	490	70	60	40
November	210	500	110	70	50
December	250	570	120	100	80
January	270	500	160	110	70
February	350	790	180	130	110
March	370	680	250	200	170
April	350	790	190	150	130
May	270	560	150	120	110
June	220	400	100	90	80
July	170	540	70	50	50
August	210	680	70	40	30
Fall	170	470	70	60	30
Winter	290	590	140	110	80
Spring	330	720	190	150	120
Summer	200	590	80	60	40
Annual	250	590	100	70	60

Values have been rounded to three significant figures.

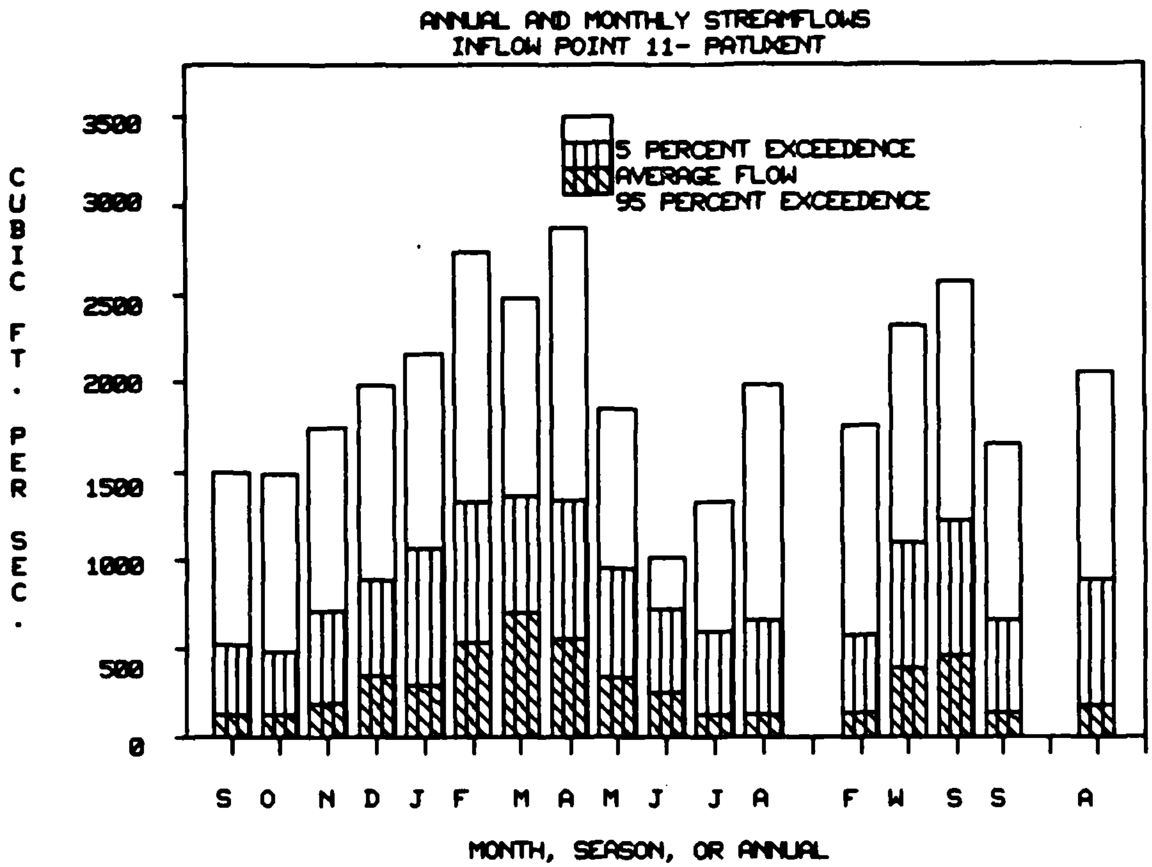
FIGURE C-IV-10



Month or Season	Average Flow cfs	5% cfs	80% cfs	90% cfs	95% cfs
			Exceedence Percentage		
September	4,020	9,630	1,520	1,380	1,160
October	5,580	17,650	1,790	1,480	1,090
November	6,120	18,850	2,470	1,780	1,360
December	9,830	25,000	3,370	2,670	1,990
January	13,330	32,190	7,030	4,600	3,470
February	17,430	37,300	8,550	6,450	4,920
March	23,100	46,250	13,400	11,100	9,920
April	19,240	38,300	10,200	8,400	6,940
May	14,180	30,000	7,020	5,700	4,960
June	9,720	23,460	4,660	3,470	2,860
July	5,420	14,220	2,760	2,150	1,650
August	5,250	14,080	2,230	1,480	1,150
Fall	5,240	16,630	1,880	1,510	1,190
Winter	13,530	36,450	5,000	3,390	2,840
Spring	18,840	39,710	9,970	7,310	6,070
Summer	6,800	18,550	2,860	2,180	1,550
Annual	11,100	32,090	3,170	2,200	1,640

Values have been rounded to three significant figures.

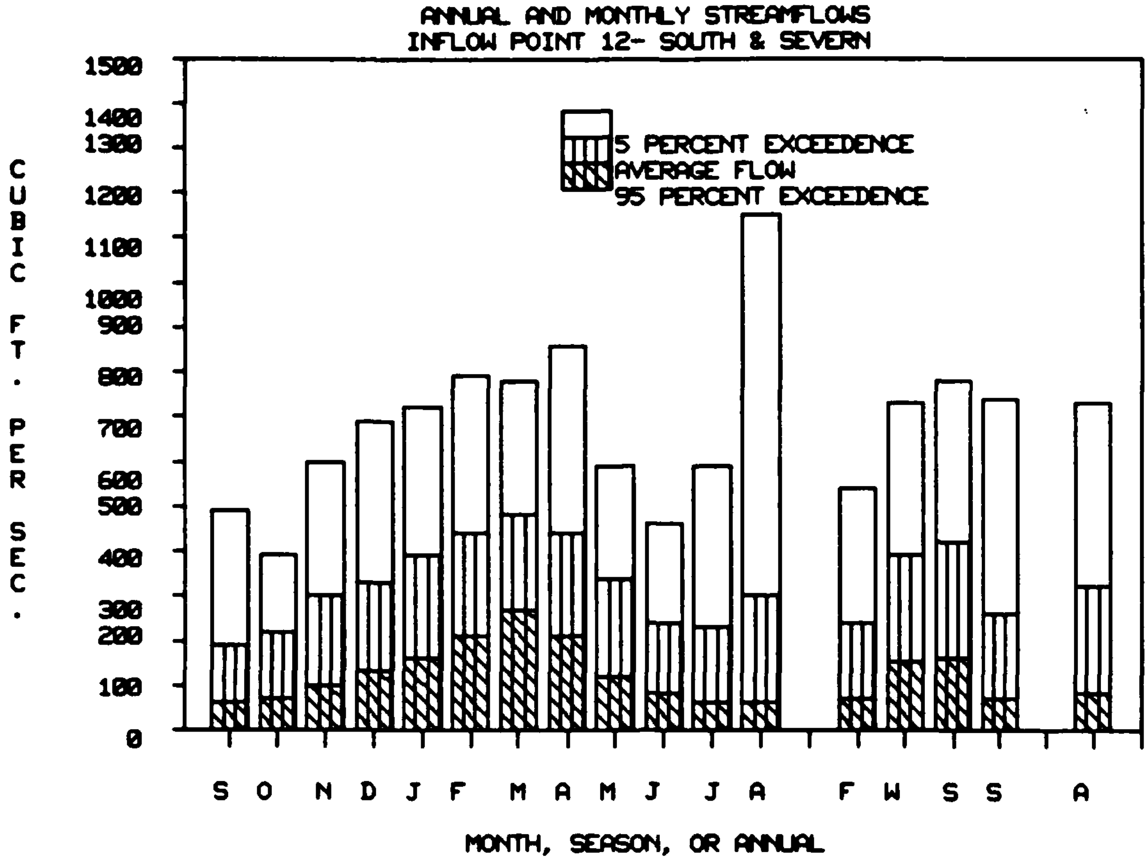
FIGURE C-IV-11



Month or Season	Average Flow cfs	Exceedence Percentage 5% cfs	80% cfs	90% cfs	95% cfs
September	520	1,490	180	150	120
October	480	1,480	240	180	130
November	710	1,750	320	230	190
December	890	1,990	480	400	340
January	1,070	2,160	660	460	300
February	1,330	2,740	760	580	530
March	1,360	2,480	970	800	700
April	1,340	2,870	740	600	550
May	950	1,850	530	380	330
June	720	1,010	370	300	250
July	600	1,320	260	150	120
August	660	1,990	250	150	120
Fall	570	1,760	230	170	140
Winter	1,100	2,320	590	470	380
Spring	1,220	2,570	700	570	460
Summer	660	1,650	290	190	140
Annual	890	2,060	360	250	180

Values have been rounded to three significant figures.

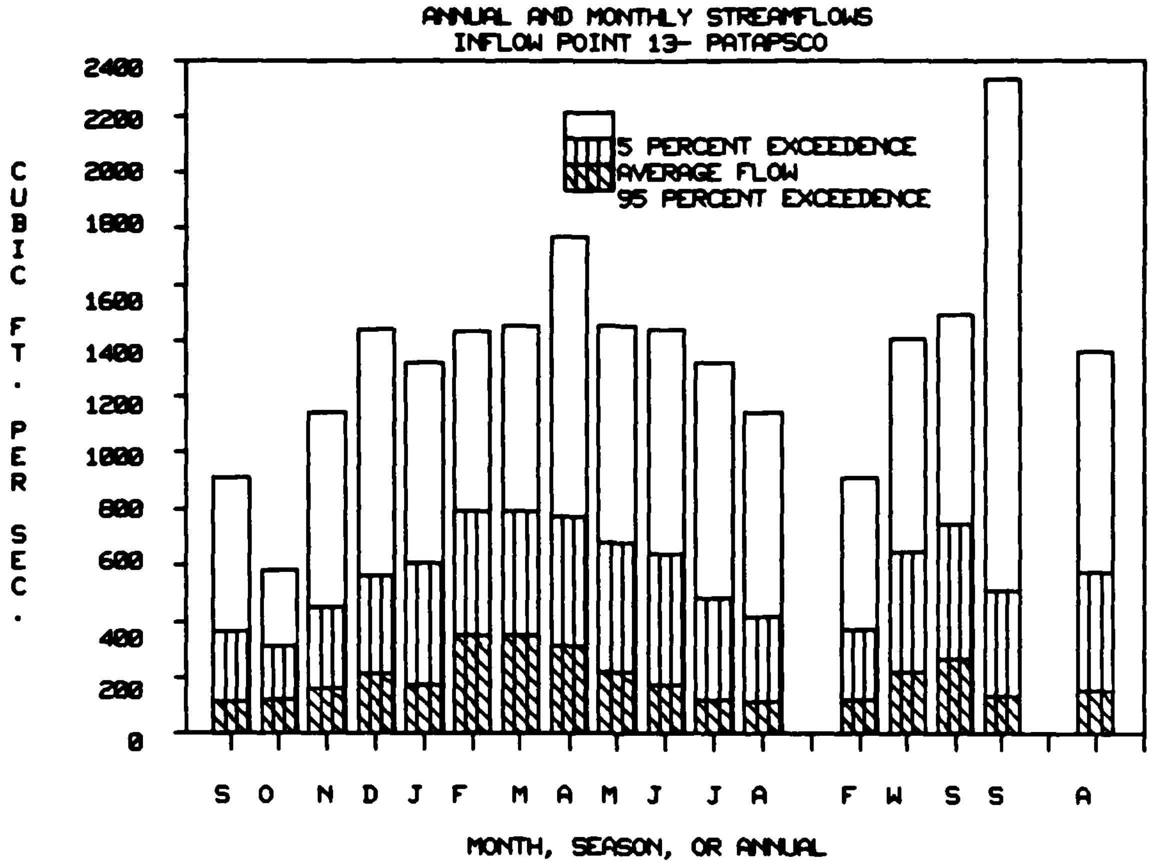
FIGURE C-IV-12



Month or Season	Average Flow cfs	Exceedence Percentage 5% cfs	80% cfs	90% cfs	95% cfs
September	190	490	90	80	60
October	220	390	100	70	70
November	300	600	160	120	100
December	330	690	220	180	130
January	390	720	270	190	160
February	440	790	280	260	210
March	480	780	340	300	270
April	440	860	290	240	210
May	340	590	180	140	120
June	240	460	150	110	80
July	230	590	110	80	60
August	300	1,150	100	70	60
Fall	240	540	110	80	70
Winter	390	730	260	200	150
Spring	420	780	270	200	160
Summer	260	740	120	80	70
Annual	320	730	160	110	80

Values have been rounded to three significant figures.

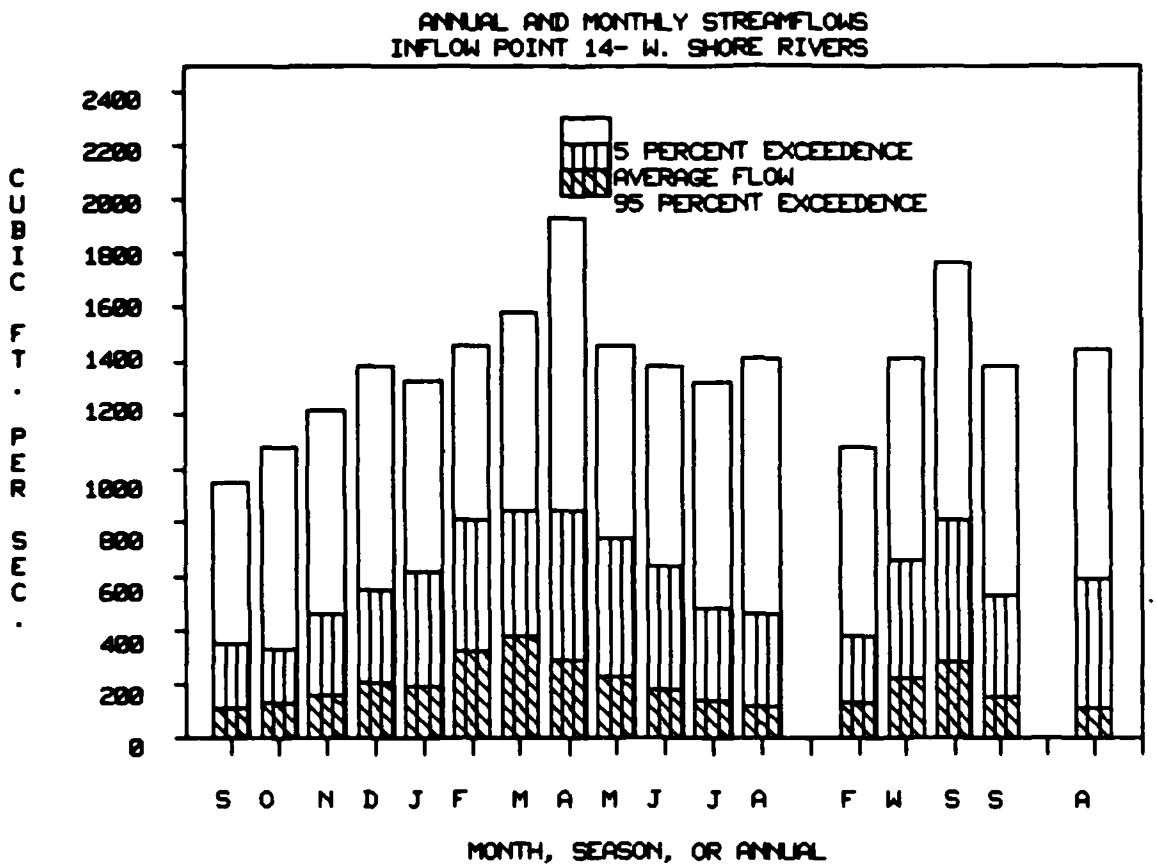
FIGURE C-IV-13



Month or Season	Average Flow cfs	5 % cfs	80 % cfs	90 % cfs	95 % cfs
			Exceedence Percentage		
September	360	910	150	120	110
October	310	580	190	150	120
November	450	1,140	240	180	160
December	560	1,440	260	220	210
January	610	1,320	330	300	170
February	790	1,430	450	400	350
March	790	1,450	520	400	350
April	770	1,770	370	330	310
May	680	1,450	340	240	220
June	640	1,440	260	200	170
July	480	1,320	220	170	120
August	420	1,140	170	130	110
Fall	370	910	190	140	120
Winter	650	1,410	330	260	220
Spring	750	1,490	400	320	260
Summer	510	2,330	210	160	130
Annual	570	1,360	250	190	150

Values have been rounded to three significant figures.

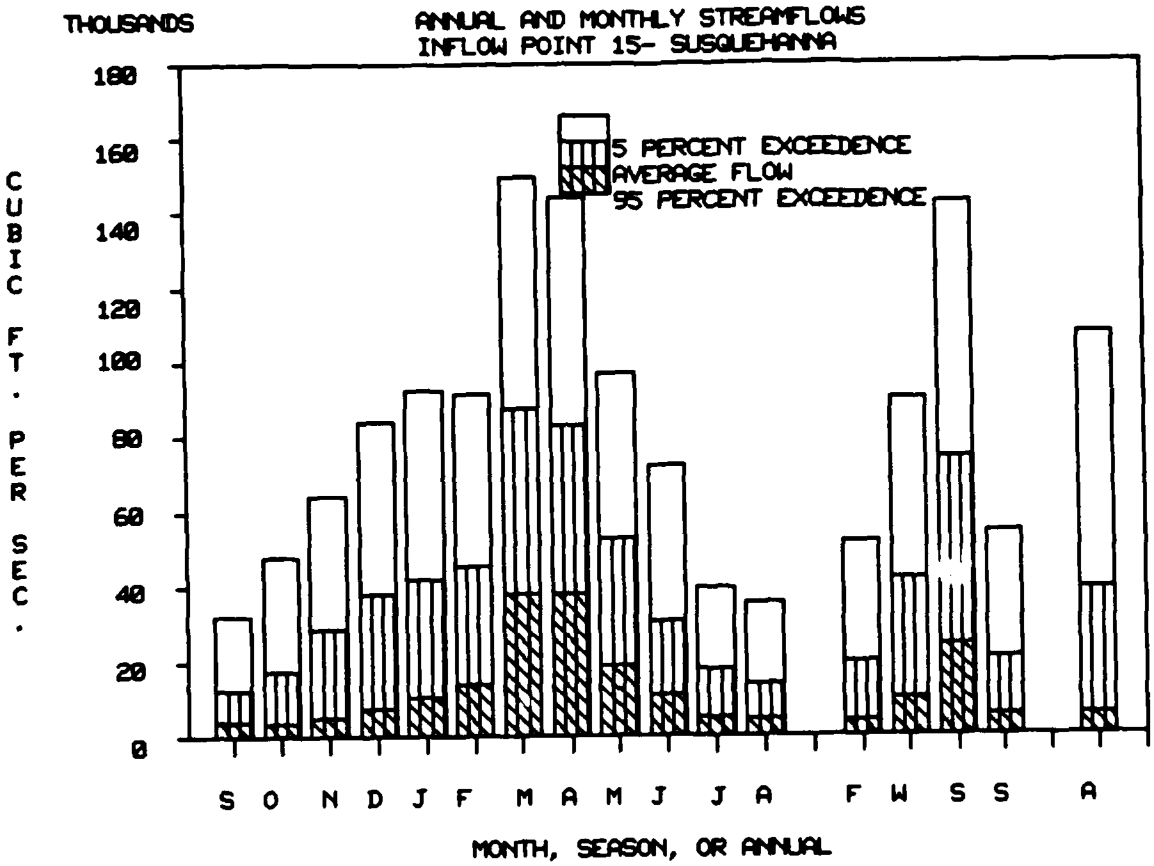
FIGURE C-IV-14



Month or Season	Average Flow cfs	5% cfs	80% cfs	90% cfs	95% cfs
		Exceedence Percentage			
September	350	950	160	130	110
October	330	1,080	190	150	130
November	460	1,220	260	220	160
December	550	1,380	260	230	210
January	620	1,330	310	260	190
February	810	1,460	450	380	320
March	850	1,580	480	420	380
April	850	1,930	380	320	290
May	740	1,460	370	270	230
June	640	1,380	260	210	180
July	480	1,320	220	170	140
August	460	1,410	180	150	120
Fall	380	1,080	190	150	130
Winter	660	1,410	310	260	220
Spring	810	1,770	420	330	280
Summer	530	1,380	210	170	150
Annual	590	1,440	250	190	110

Values have been rounded to three significant figures.

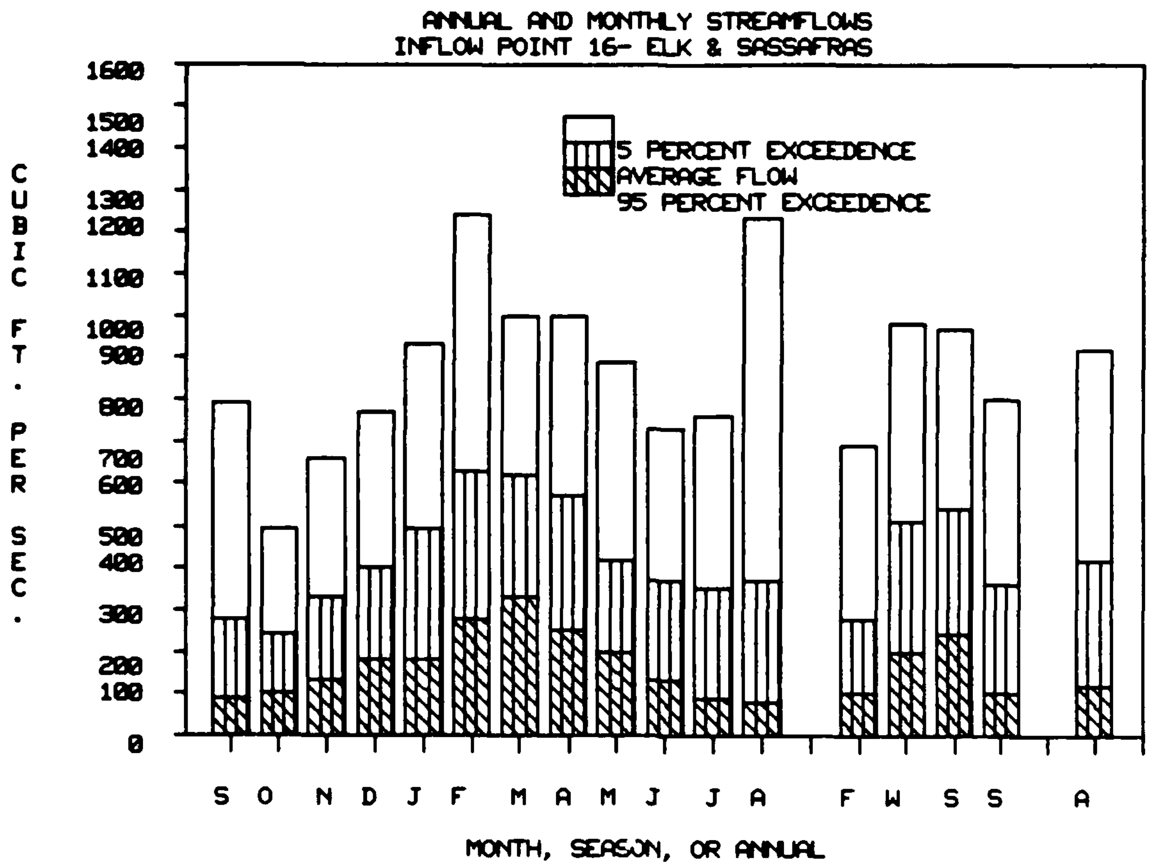
FIGURE C-IV-15



Month or Season	Average Flow cfs	Exceedence Percentage 5 % cfs	80 % cfs	90 % cfs	95 % cfs
September	12,500	32,080	5,420	4,540	4,020
October	17,490	47,670	5,510	4,260	3,290
November	28,890	64,170	10,300	7,330	4,720
December	38,020	84,170	16,600	10,300	7,440
January	42,030	92,780	19,800	16,100	10,420
February	45,710	91,330	22,800	18,300	14,170
March	87,840	149,640	56,500	44,700	37,920
April	83,170	144,010	56,600	46,700	37,920
May	52,650	97,110	28,000	22,100	19,170
June	30,820	72,220	14,300	12,000	10,880
July	17,870	39,670	8,740	6,860	5,030
August	13,840	35,670	6,320	5,290	4,540
Fall	19,630	51,870	6,060	4,750	3,930
Winter	41,920	90,000	20,140	14,900	10,100
Spring	74,550	142,650	43,690	31,880	24,140
Summer	20,840	54,170	8,680	6,530	5,390
Annual	39,240	107,100	11,400	7,000	5,300

Values have been rounded to three significant figures.

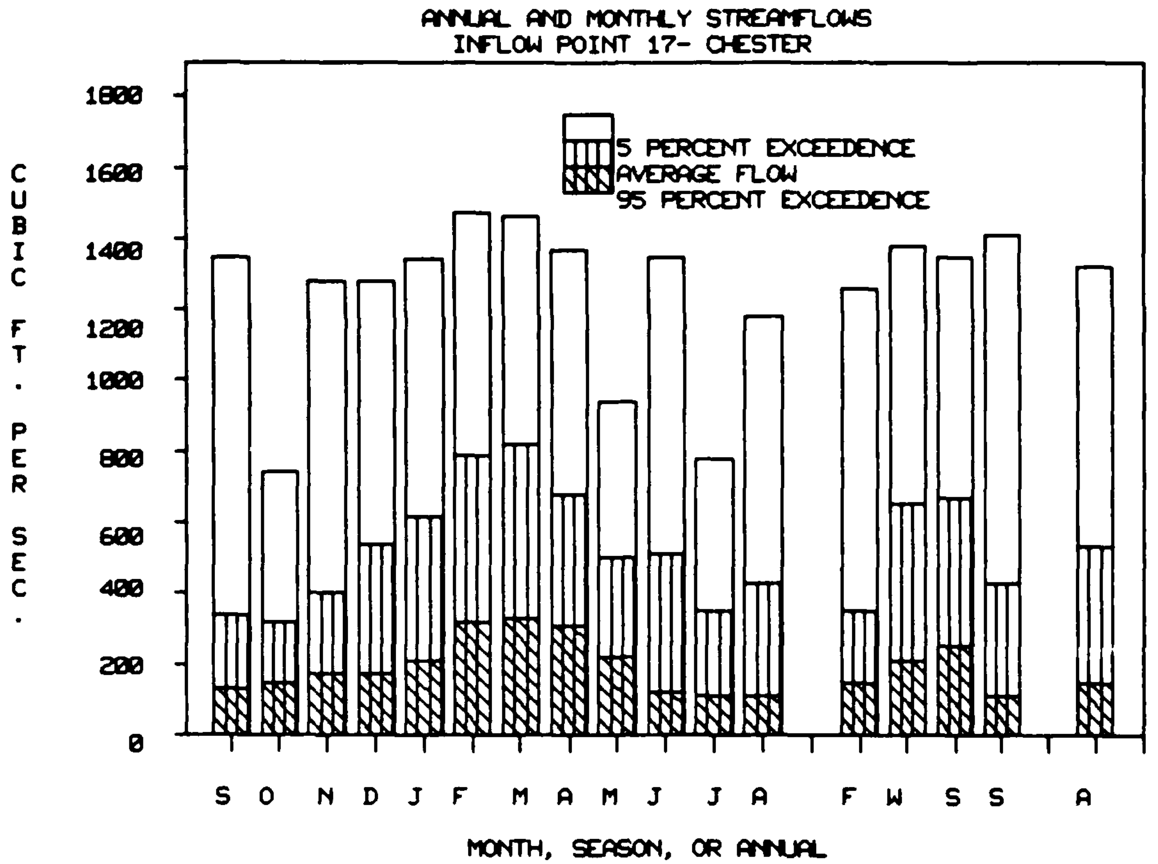
FIGURE C-IV-16



Month or Season	Average Flow cfs	5% cfs	80% cfs	90% cfs	95% cfs
		Exceedence Percentage			
September	280	790	140	110	90
October	240	490	130	110	100
November	330	660	180	150	130
December	400	770	240	210	180
January	490	930	310	220	180
February	630	1,240	400	320	280
March	620	1,000	440	380	330
April	570	1,000	330	280	250
May	420	890	280	230	200
June	370	730	210	160	130
July	350	760	180	110	90
August	370	1,230	150	110	80
Fall	280	690	150	120	100
Winter	510	980	290	230	200
Spring	540	970	330	280	240
Summer	360	800	170	130	100
Annual	420	920	220	160	120

Values have been rounded to three significant figures.

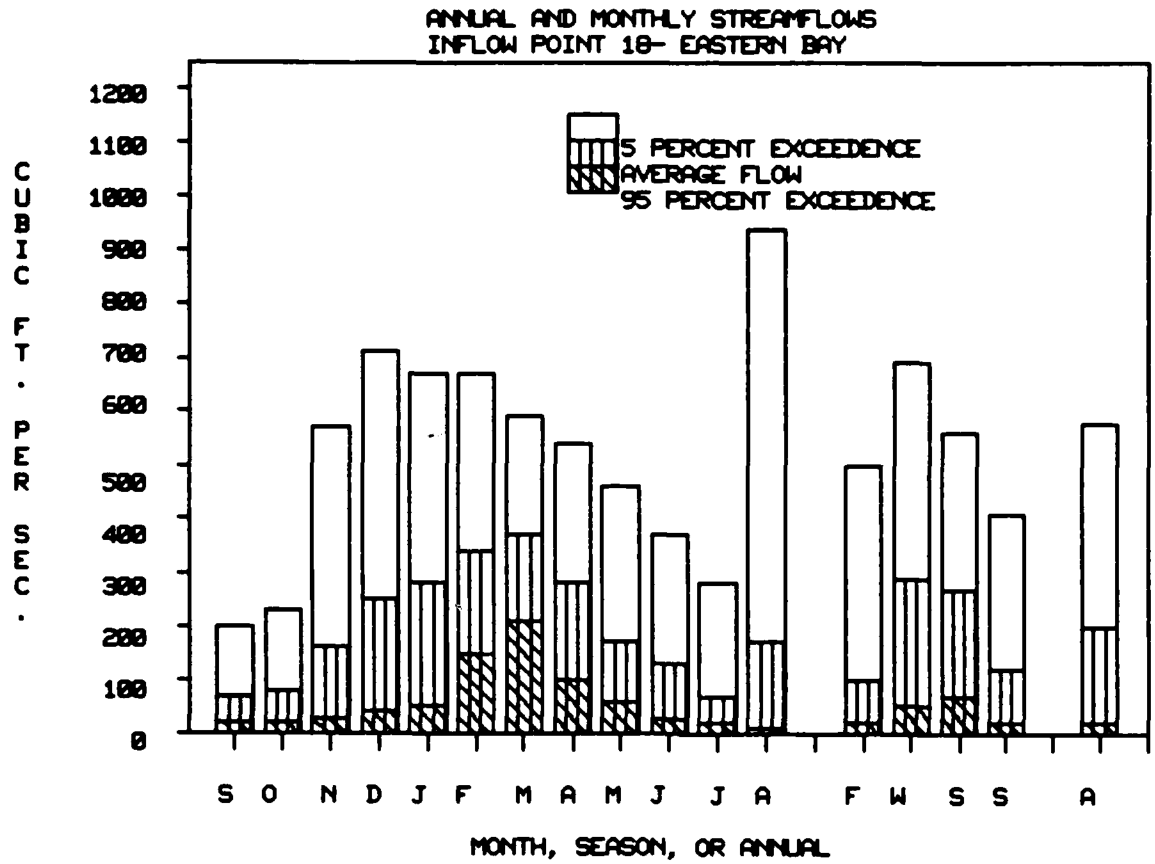
FIGURE C-IV-17



Month or Season	Average Flow cfs	5% cfs	80% cfs	90% cfs	95% cfs
		Exceedence Percentage			
September	340	1,350	170	150	130
October	320	740	170	160	150
November	400	1,280	220	200	170
December	540	1,280	240	210	170
January	620	1,340	310	230	210
February	790	1,470	460	380	320
March	820	1,460	560	460	330
April	680	1,370	400	340	310
May	500	940	300	260	220
June	510	1,350	210	160	120
July	350	780	160	130	110
August	430	1,180	170	140	110
Fall	350	1,260	180	160	150
Winter	650	1,380	310	230	210
Spring	670	1,350	380	310	250
Summer	430	1,410	180	140	110
Annual	530	1,320	220	170	150

Values have been rounded to three significant figures.

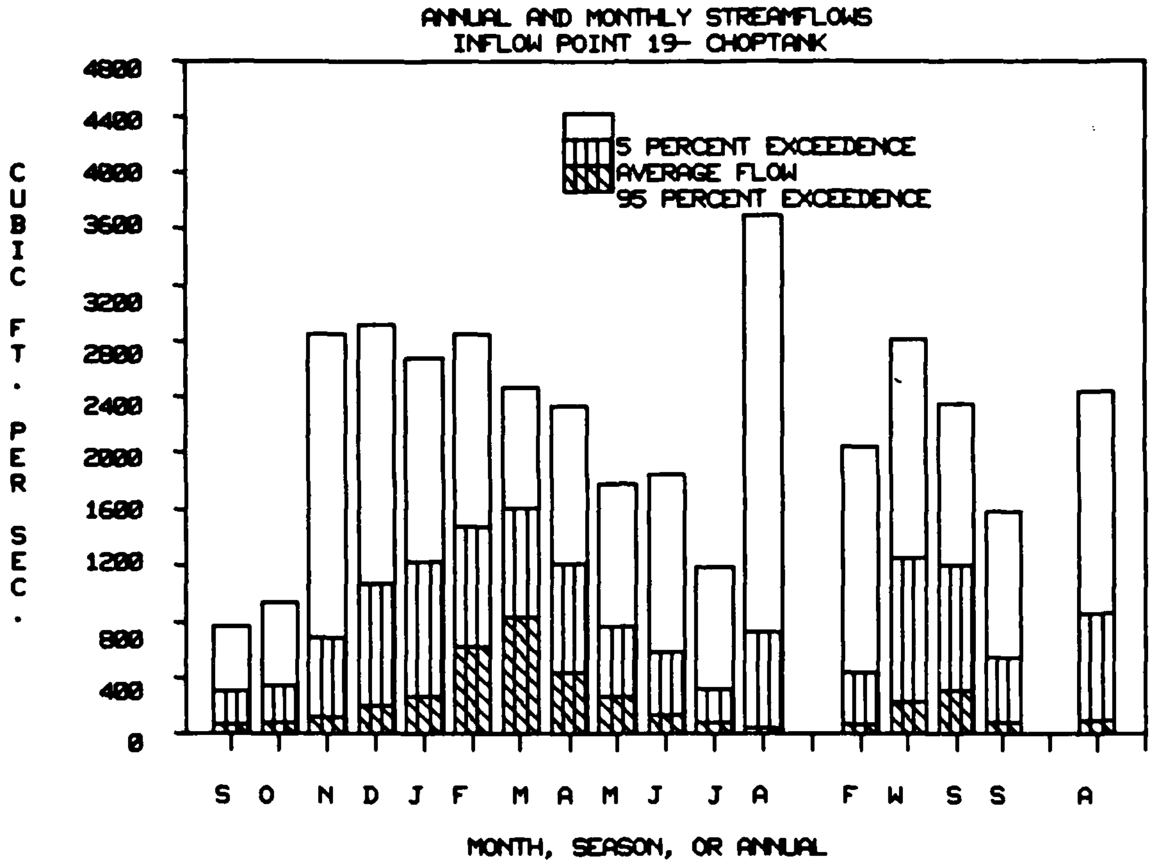
FIGURE C-IV-18



Month or Season	Average Flow cfs	5% cfs	80% cfs	90% cfs	95% cfs
		Exceedence Percentage			
September	70	200	20	20	20
October	80	230	20	20	20
November	160	570	50	40	30
December	250	710	70	50	40
January	280	670	110	70	50
February	340	670	190	160	150
March	370	590	270	240	210
April	280	540	140	120	100
May	170	460	80	70	60
June	130	370	50	40	30
July	70	280	20	20	20
August	170	940	20	20	10
Fall	100	500	30	20	20
Winter	290	690	130	70	50
Spring	270	560	130	80	70
Summer	120	410	30	20	20
Annual	200	580	40	30	20

Values have been rounded to three significant figures.

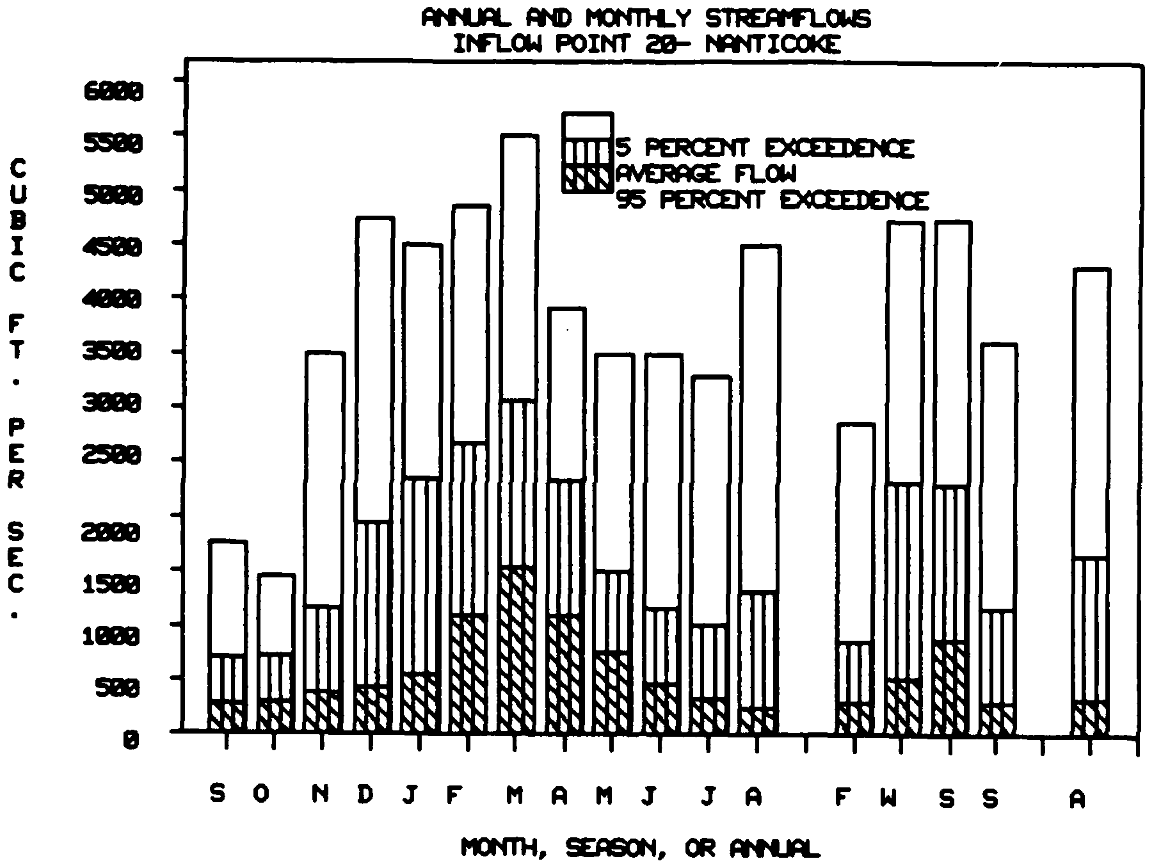
FIGURE C-IV-19



Month or Season	Average Flow cfs	5% cfs	80% cfs	90% cfs	95% cfs
			Exceedence Percentage		
September	300	770	90	70	70
October	340	940	100	90	80
November	690	2,850	190	160	120
December	1,070	2,920	310	220	200
January	1,230	2,680	610	330	270
February	1,470	2,850	810	680	620
March	1,610	2,470	1,110	960	830
April	1,220	2,340	680	530	430
May	760	1,780	340	280	270
June	580	1,850	210	160	130
July	320	1,180	100	90	80
August	720	3,690	90	70	40
Fall	440	2,040	110	90	70
Winter	1,260	2,810	560	320	220
Spring	1,200	2,350	590	380	300
Summer	540	1,580	120	90	80
Annual	860	2,450	180	110	90

Values have been rounded to three significant figures.

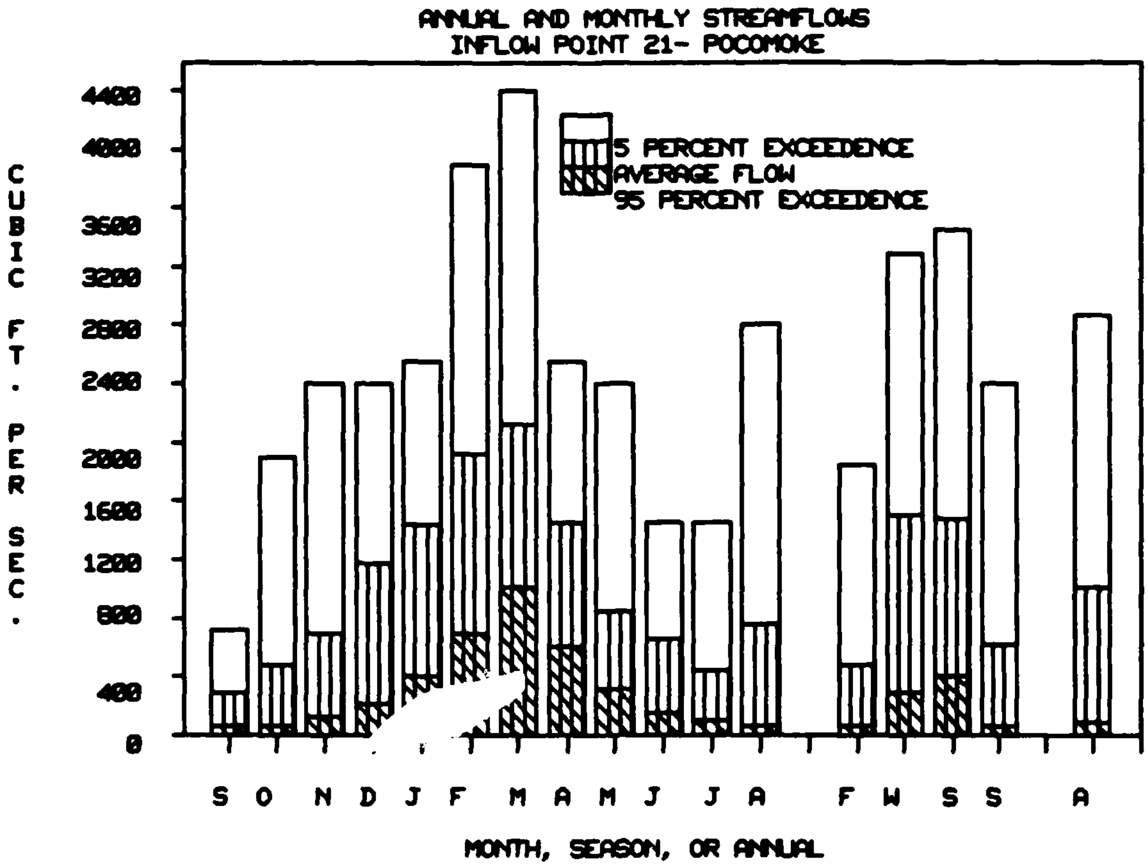
FIGURE C-IV-20



Month or Season	Average Flow cfs	5 % cfs	80 % cfs	90 % cfs	95 % cfs
			Exceedence Percentage		
September	700	1,750	330	290	270
October	720	1,450	360	310	290
November	1,170	3,500	550	430	380
December	1,940	4,750	600	500	430
January	2,360	4,500	1,120	800	550
February	2,670	4,870	1,370	1,190	1,090
March	3,070	5,500	1,810	1,630	1,530
April	2,340	3,920	1,370	1,190	1,090
May	1,500	3,500	910	830	750
June	1,170	3,500	580	500	450
July	1,010	3,300	460	400	330
August	1,320	4,500	320	270	240
Fall	860	2,870	370	320	290
Winter	2,320	4,720	1,110	700	510
Spring	2,300	4,750	1,240	1,000	870
Summer	1,170	3,620	450	340	280
Annual	1,660	4,310	550	400	320

Values have been rounded to three significant figures.

FIGURE C-IV-21



Month or Season	Average Flow cfs	Exceedence Percentage 5% cfs	80% cfs	90% cfs	95% cfs
September	290	720	100	70	60
October	480	1,900	120	90	70
November	690	2,400	240	140	120
December	1,180	2,400	680	230	210
January	1,440	2,550	650	470	410
February	1,920	3,900	940	820	700
March	2,120	4,400	1,210	1,080	1,010
April	1,460	2,550	750	660	610
May	850	2,400	430	370	310
June	650	1,450	230	180	150
July	450	1,450	160	120	100
August	760	2,800	80	60	60
Fall	490	1,850	130	90	70
Winter	1,510	3,290	780	520	290
Spring	1,480	3,460	610	450	410
Summer	620	2,400	160	100	70
Annual	1,020	2,870	220	100	90

Values have been rounded to three significant figures.

FIGURE C-IV-22

CHAPTER V

FUTURE STREAMFLOWS

In order to predict future salinities in the Chesapeake Bay estuarine system and the resulting biological effects, the future freshwater inflows must first be computed. Although there are statistical methods for making these projections, the ones used in this report are based on historical records.

One of the largest factors that will affect streamflows in the future is the consumptive use and resulting loss of freshwater. The following sections give the methodology for computing the future consumptive losses and their effect on historical streamflows.

CONSUMPTIVE USES OF WATER

Historically, an ever increasing amount of water has been withdrawn from the rivers tributary to Chesapeake Bay to accommodate domestic, commercial and industrial related needs. Although most of this water is returned to the rivers at, or near, the point it is withdrawn, a significant portion of it is used consumptively. For instance, from 10 percent to 25 percent of the water withdrawn by a typical municipality is lost through pipe leaks, irrigation of lawns, drinking and other associated factors. Of the water used for irrigation purposes 75 percent is either never returned to the river or takes so long that it could be considered to have been consumed. In addition, many industries use the water in various processes incurring losses ranging from 3 percent to 26 percent. Similarily power plants with once through cooling loose about 2 percent of the water withdrawn. With a trend toward cooling towers, these losses will dramatically increase to an estimated 13 percent.

The demand for and consumptive use of water is expected to continually increase into the foreseeable future. This increase will reduce tne freshwater inflows of the rivers tributary to the Bay which will in turn, cause higher salinities throughout the estuarine system. In order to determine the extent of this change, future stream flows were computed. The steps involved in this were as follows:

1. Determine both the existing and future average annual water demands.
2. Determine both the existing and future average annual consumptive losses.
3. Determine the monthly variations in demands and losses.
4. Determine that increment of increased consumptive losses which will occur between the years 1965 and 2020.
5. Adjust the historic hydrographs of freshwater inflow to incorporate the incremental increase in future consumptive water use.

Both the North Atlantic Regional Water Resources Study (NAR) published in 1972 by the Corps of Engineers and the Second National Water Assessment prepared by the U.S. Water Resources Council in December 1978 treated in detail the demands and consumptive uses of water in the Chesapeake Bay Basin. The NAR Study addressed the planning horizon from the year 1965 to 2020 while the National Assessment focused on the years 1975 to 2000.

Water demands and consumptive losses for this Low Freshwater Inflow Study were based, for the most part, on the findings of these reports. Demands and losses for the 1960's

drought years were taken from the NAR Study. However, the projections of future water use included in that report were based on OBERS Series C economic and demographic data, while Federal guidance in effect at the time our projections were done dictated the use of Series E data. Water demands and losses for the year 2020 were therefore computed by extending the Series E year 1975 to 2000 projections of the National Assessment. In the National Assessment, water demands and consumptive losses were displayed only for large hydrologic areas known as Aggregated Sub-Regions (ASR's). As shown on Figure C-V-1, the Chesapeake Bay Drainage Basin is comprised of the following three sub-regions:

ASR 204 - Susquehanna River Basin
ASR 206 - Potomac River Basin
ASR 205 - Remainder of Chesapeake Bay Basin

Projections of year 2020 water uses for the Low Freshwater Inflow Study were computed as a function of these sub-regions. It was then necessary to use demographic and other information derived from a variety of reports to assist in distributing these water use data among the hydrologic areas contiguous to the 21 freshwater inflow locations established for this study and the hydraulic model test (see Table C-V-1). Information from other studies was also used to determine the monthly variations in water demands and consumptive losses since these data were not available from the National Assessment at the time that this work was being done for this study. A detailed description of the methodology used in computing water use and adjusting the hydrographs of freshwater inflows is included in the following sections.

Public, Domestic and Commercial

General. This category of water use encompases a variety of needs. Domestic demands, both urban and rural, include those of the household, e.g., food preparation, washing, lawn watering and sanitation. The commercial category includes restaurants, hotels, laundries and car washes. Institutional uses, such as hospitals and schools are also included in this category. Public demands include fire protection, street cleaning and water use in government buildings and institutions.

Methodology. Demographic and public, domestic, and commercial water use data for the years 1965 to 2020 are shown on Table C-V-2 for each of the 3 ASR's contained in the Chesapeake Bay Basin. As previously noted, data for the year 1965 were taken from the NAR Study. Data for that study were obtained from an inventory of all public water supply systems. This inventory included the name of each utility, ownership, county location, water source, annual water production and population served.

The data for the years 1975 to 2000 were taken from the National Assessment. The methodology used in extending to the year 2020 these public, domestic and commercial water use data of the National Assessment was based upon the findings of the NAR Study and the Chesapeake Bay Future Conditions Report. It was concluded in both of these studies that, during the period encompassing the years 2000 to 2020, per capita water use will increase at one half of the rate expected between the years 1985 and 2000. Applying this conclusion to the water use data from the National Assessment yielded the per capita water use rates for the year 2020 shown on Table C-V-2.

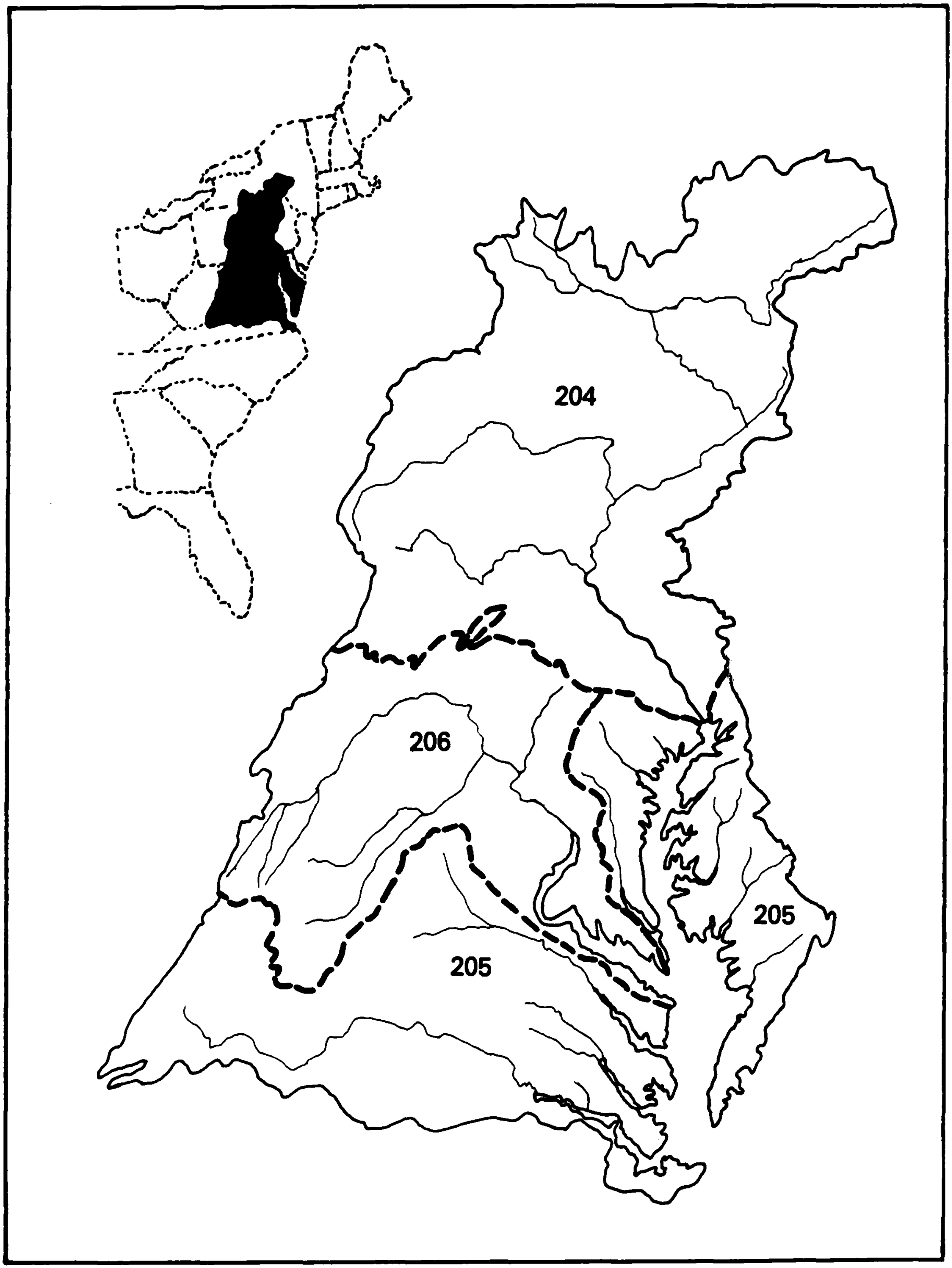


FIGURE C-V-1 AGGREGATED SUB-REGIONS

TABLE C-V-1

HYDROLOGIC AREAS IN EACH ASR

ASR	Area	Freshwater Inflow Point
204	Susquehanna River Basin	15
205	Upper/Lower Chesapeake Bay	
	James River Basin	
	Nansemond River	1
	Chickahominy River	2
	Appomattox River	3
	James River (above Richmond)	4
	York River Basin	5
	Rappahannock River Basin	6
	Baltimore Area	
	Patuxent River	11
	Severn River	12
	Patapsco River	13
	Gunpowder River	14
	Eastern Shore	
	Bohemia River	16
	Chester River	17
	Wye River	18
	Choptank River	19
	Nanticoke River	20
	Pocomoke River	21
206	Potomac River Basin	
	Lower Potomac (Wicomico)	7
	Occoquan Creek	8
	Anacostia River	9
	Potomac River (above Washington)	10

TABLE C-V-2

PUBLIC, DOMESTIC, & COMMERCIAL
WATER WITHDRAWAL & CONSUMPTIVE LOSS
1965-2020

Parameter	1965[1]	1975[2]	1985[2]	2000[2]	2020[3]
ASR 204					
Water use, mgd	441	581	649	739	811
Total Population (Series E), 1000's	NA	3,669	3,947	4,302	4,668
Use rate, gpcd	NA	158.4	164.4	169.7	173.7
Consumption, mgd	74	99	109	121	136
ASR 205					
Water use, mgd	345	454	520	5951	679
Total Population (Series E), 1000's	NA	4,796	5,135	5,732	6,426
Use Rate, gpcd	NA	94.7	101.3	103.8	105.5
Consumption, mgd	51	67	78	87	137
ASR 206					
Water Use, mgd	366	483	608	797	1040
Total Population (Series E), 1000's	NA	4,211	5,082	6,547	8,453
Use Rate, gpcd	NA	114.7	119.6	121.7	123.1
Consumption, mgd	37	49	64	82	106

1 From NAR Study
2 Derived from the 1978 Second National Water Assessment
3 Computed from the given Series E population of OBERS and projected water use roles.

Average annual water demands were then computed by multiplying these per capita use rates by the OBERS Series E population projections for the year 2020.

Average monthly water use was derived by applying to the annual demands, the factors shown on Table C-V-3. These factors are the average of those contained in a report entitled Washington Metropolitan Water Supply published under the auspices of the Northeastern United States Water Supply Study.

TABLE C-V-3

MONTHLY DEMAND DISTRIBUTION FACTORS
(Ratio of Monthly Demands to Average Annual Demands)

Jan	.87	Jul	1.20
Feb	.86	Aug	1.16
Mar	.90	Sep	1.10
Apr	.93	Oct	1.00
May	1.01	Nov	.95
Jun	1.10	Dec	.92

It was determined that the amount of water used consumptively varies with both the month of the year and the geographic region (ASR) in which it occurred. The monthly variations in consumptive losses was derived from the Susquehanna River Basin Study. These were adjusted to reflect geographic related variations as determined in the National Assessment. The result was a factor that are representative of the percentage of water that is used consumptively in each region during each month of the year. These factors are shown by ASR on Table C-V-4.

TABLE C-V-4

MONTHLY CONSUMPTIVE LOSS FACTORS
(Ratio of Monthly Losses to Monthly Demands)

MONTH	ASR 204	ASR 205	ASR 206
Jan	.11	.10	.07
Feb	.10	.09	.06
Mar	.13	.12	.08
Apr	.13	.12	.08
May	.17	.15	.10
Jun	.20	.18	.12
Jul	.25	.22	.15
Aug	.23	.20	.14
Sep	.19	.16	.12
Oct	.17	.15	.10
Nov	.14	.12	.09
Dec	.13	.11	.08

Shown on Tables C-V-7 and C-V-8 (see the back of this report) are the year 1965 and 2020 average annual water uses and consumptive losses for each of the hydrologic sub-basins contigious to the aforedescribed 21 freshwater inflow points. The distribution of these demands and losses from the ASR level to these sub-basins was based upon county populations developed by the Bureau of Economic Analysis. Populations for counties in Maryland were presented by the Bureau in a report prepared for the Maryland Department of Transportation entitled Regional Economic Activity in Maryland while the data for Virginia were unpublished.

Manufacturing

General. In general, this category of water use can be broken down into 4 classifications: process, boiler feed, cooling, and sanitary. The quality requirements vary widely depending upon the industry and the type of use. Whereas cooling water can in some cases be of almost any quality, boiler feedwater requires stringent quality control to avoid scale buildup.

Presently, water withdrawn for industrial purposes is recycled an average of 2 times before it is returned to the water source. By the year 2020 this is anticipated to increase ten fold because of pollution control limitations on waste discharges and efforts to reclaim byproducts. This could result in an increased consumptive use of water.

Methodology. As previously stated, the existing water demands and consumptive losses for manufacturing were obtained from the NAR Study. These were based on generalized data presented in various publications of the Bureau of the Census and information from existing reports or studies.

For the year 2020, manufacturing demands and consumption bases were projected for the Chesapeake Bay Study by the Industrial Trade Administration (ITA) of the Department of Commerce using the same methodology as it had used in making the year 2000 projections for the National Assessment. This methodology included the use of a forecasting model previously developed by the Office of Business Research and Analysis (OBRA). This model goes through four stages of calculations. First, the base year estimates are made for each industry in each region. This was accomplished by summarizing the data from a 1971 inventory of plants using 10 million gallons or more per year. This inventory included intake, gross water used and discharge for each plant. By subtracting the discharge from the intake totals, the base year losses were determined. Second, future water use practices and economic growth were calculated for each industry in each region. During this stage, average consumption roles for 37 water-intensive SIC 4-digit industries were computed assuming that cooling towers would be used to recirculate the heated wastewaters. Projections of gross water demand were made by relating it to a 1967 constant dollar "gross product" originated by an industry. Third, forecasts are made using the estimates derived from the first two stages. In this stage, the gross water use is multiplied by the consumption rate to determine the projected consumptive losses. Finally, the forecasts for each industry are summed to produce regional totals for the entire manufacturing sector, and the data are converted from millions of gallons per year to millions of gallons per month and millions of gallons per day. A key assumption made by the ITA was that manufacturers will have achieved high optimum recirculation rates by the year 2000 and as a result, further improvements are unlikely or would be insignificant. Therefore, manufacturing water intake would be at a minimum in 2000 and begin to increase substantially to 2020, paralleling increased manufacturing production. Further information on this model and the methodology used can be found in the Baltimore District Office.

The distribution of water demands and consumptive losses from the ASR to the 21 hydrologic areas was based upon data in the Virginia State Water Control Board report, the 1972 Census of Manufactures and various county water and sewer plans. The resulting water demands and consumptive losses are shown on Tables C-V-7 and C-V-8.

Energy Production

General. The primary use of water for energy purposes is for steam condensing at electrical power plants. Although large amounts of water are withdrawn from a river in the once-through cooling system for steam powered generators, only 2 percent is not returned to the water source. However, it is anticipated that most power plants will convert to cooling towers in order to meet water quality standards. About 13 percent of the water withdrawn is lost in this process. Because of this, the electrical power industry will be the second largest consumptive user of water in the Chesapeake Bay Basin by the year 2020.

Methodology. Year 1965 water use by the power industry was derived from two sources. In the Susquehanna River Basin, consumptive losses were taken from the Pennsylvania Master Siting Study, June 1977 prepared for the Pennsylvania Department of Environmental Resources.

Because there were no valid statistics available for the remainder of the Chesapeake Bay Basin, a detailed investigation was done. It was found that no power plants had begun operation during the period 1965 to 1975 and that there had been little change in operating procedures. It was therefore, determined that the data for the year 1975 contained in the National Assessment are representative of the year 1965 consumptive use of water by the power industry.

Water use and consumption for power from both fresh and brackish waters in the Chesapeake Bay Basin were projected to the year 2020 by the New York Regional Office of the Federal Energy Regulatory Commission. The analysis, conducted on a plant by-plant basis, was based on the assumption that future intake will decrease markedly in light of trends toward limiting heated water discharge. Siting assumptions were made for particular plants that are expected to come on line in each of the goal years. It was also assumed that other plants would be retired as they become outdated.

Since the study by the FERC was site specific, it was possible to distribute the demands and consumptive losses for both the years 1965 and 2020 to the 21 inflow point areas based on the location of each of the plants. The total estimated water withdrawals and consumptive losses for energy production for the years 1965 and 2020 are shown on Tables C-V-7 and C-V-8, respectively.

Irrigation

General. Nationally, more water is used for irrigation than for any other purpose. It accounts for 82 percent of the total water consumed. Within the Chesapeake Bay Basin, however, it accounts for only 10 percent of the total average annual consumptive losses. Although this appears small, it becomes quite significant when it is considered that over 90 percent of this loss occurs during June, July and August. During the month of July, when over 40 percent of the total irrigation demands occur, it is the second largest water use in the Basin. This is compounded by the fact that the largest irrigation demands occur during the period when stream flows are at their lowest.

Methodology. As with most of the other water uses, the amount of water required for irrigation during the 1960's drought was taken from the NAR Study. The data used for that study were obtained from the U.S. Census of Agriculture and reflect the water use in the year 1964.

Projections of irrigation water needs in the year 2020 were based on the year 1975 and 2000 annual demand rates of the National Assessment. These were based upon projected increases in population, per capita food consumption, amount of lands available for agriculture, irrigated lands needed to support the crops required, and the amounts of water required for the various types of crops.

Only average annual irrigation rates were shown in the National Assessment. But, irrigation is normally done only during the months of May through September, with peak rates occurring in June and July. The conversion from average annual to monthly volumes was done using the percentage distribution shown on Table C-V-5.

TABLE C-V-5

MONTHLY DISTRIBUTION OF IRRIGATION REQUIREMENTS

Month	Percent[1]
May	6.2
June	17.6
July	43.8
August	30.8
September	1.6
TOTAL	100.0

(1) From June 1976 SCS Report entitled Crop Consumption Irrigation Requirements and Irrigation Efficiency Coefficients for the United States

These percentages were taken from a report entitled Crop Consumption Irrigation Requirements and Irrigation Coefficients for the United States published by the Conservation Service in June 1976. The monthly volumes were then converted to flows based on the number of days in each month.

Based on the projections in the National Assessment, it was estimated that approximately 75 percent of the water used in irrigation would be consumed and therefore, only 25 percent of it would be returned to the river. Table C-V-6 is a summary of the demands and losses for the 5 month irrigation period for the years 1965 and 2020.

These requirements were distributed among the hydrologic sub-basins contigious to each of the 21 freshwater inflow points using data compiled in the Chesapeake Bay Future Conditions Report, Virginia State Water Control Board reports, the NAR Study, and the National Assessment.

TABLE C-V-6

IRRIGATION REQUIREMENTS & CONSUMPTIVE LOSSES

Month	1965 Demand (mgd)	1965 Loss (mgd)	2020 Demand (mgd)	2020 Loss (mgd)
May	45.5	34.2	166.5	124.9
June	133.4	100.0	488.4	366.4
July	321.3	241.0	1,176.2	882.2
August	225.9	169.4	827.1	620.4
September	12.2	9.1	44.4	33.3
Annual Average	62	48	228	171

The average annual demands and consumptive losses for 1965 and 2020 for the 21 areas are shown on Tables C-V-7 and C-V-8, respectively.

Livestock

General. Although the amount of water consumed by livestock in 1965 was small, it accounted for a higher consumptive loss than either energy production or minerals. However, because of the larger rate of increase of these other uses, it will account for the least amount of water loss by 2020.

Methodology. For the 1960's drought condition, the amount of water used for livestock watering was taken from the NAR Study. This study obtained the livestock population for 1964 from agricultural census reports. These data were then used as the basis for determining the water requirements for all livestock except dairy cows and chickens. The water requirements for dairy cattle and laying hens were based on the water required to produce a specific unit of product with the number of units being determined from farm product sales. Water rates for animals or water required per unit of product were based on published reports.

The projections to the year 2020 were done similarly to those for irrigation in that the data from 1975 to 2000 in the National Assessment were used as an historic base to extrapolate the water requirements to 2020. Based on projections in the National Assessment, none of the water used for livestock is returned to the stream and therefore, is considered to be a 100 percent consumptive loss. The livestock water requirements were then distributed among the hydrologic sub-basins contigious to each of the 21 freshwater inflow points using data compiled in the 1974 Census of Agriculture, the Chesapeake Bay Future Conditions Report, Virginia State Water Control Board reports, the NAR Study, and the National Assessment.

The water demands and consumptive losses for 1965 and 2020 for all 21 areas are shown on Tables C-V-7 and C-V-8 respectively.

TABLE C-V-7
FRESHWATER REQUIREMENTS AND CONSUMPTIVE LOSSES BY USE FOR 1965
(MGD)

ASA	AREA	INFLOW POINT SUB-AREA	PUBLIC-DOMESTIC-COMM REQ'D	PUBLIC-DOMESTIC-COMM LOSS	MANUFACTURING REQ'D	MANUFACTURING LOSS	POWER REQ'D	POWER LOSS	IRRIGATION REQ'D	IRRIGATION LOSS	LIVESTOCK REQ'D	LIVESTOCK LOSS	MINERALS REQ'D	MINERALS LOSS
204	SUSQUEHANNA RIVER BASIN	15	467 1/	100 1/	315	46	550	11	10	8	19	19	70	12
205	UPPER LOWER CHESAPEAKE BAY													
	NANSEMOND RIVER	1	66	10	82	6	N/A	0	1	1	0	0	2	0
	CHICKAHOMINY RIVER	2	5	1	0	0	N/A	0	0	0	0	0	6	1
	APPOMATTOX RIVER	3	9	1	0	0	N/A	6	1	1	2	2	2	0
	JAMES RIVER (above Richmond)	4	61	9	302	22	N/A	0	3	2	1	1	15	3
	YORK RIVER	5	11	2	77	26	N/A	0	1	1	0	0	1	0
	RAPPAHANNOCK RIVER	6	9	1	99	7	N/A	0	1	1	2	2	1	0
	PATUXENT RIVER	11	8	1	2	0.5	N/A	0	3	2	1	1	5	1
	SEVERN RIVER	12	11	2	6	1	N/A	0	1	1	0	0	1	0
	PATAPSCO RIVER	13	128	19	168	20	N/A	0	0	0	2	2	6	1
	GUNPOWDER RIVER	14	9	1	4	0.5	N/A	0	3	2	1	1	4	1
	BOHEMIA RIVER	16	4	0	13	1	N/A	0	0	0	1	1	2	1
	CHESTER RIVER	17	2	0	6	1	N/A	0	2	2	1	1	0	0
	WYE RIVER	18	0	0	0	0	N/A	0	0	0	0	0	0	0
	CHOPTANK RIVER	19	5	1	25	1	N/A	0	4	3	0	0	0	0
	NANTICOKE RIVER	20	12	2	63	3	N/A	0	4	3	2	2	2	0
	POCOMOKE RIVER	21	5	1	22	1	N/A	0	20	15	0	0	1	0
	TOTAL (205)		345	51	869	90	N/A	6	44	34	13	13	48	8
206	POTOMAC RIVER BASIN													
	LOWER POTOMAC (Wicomico)	7	13	1	0	0	N/A	0	0	0	0	0	4	1
	OCCOQUAN CREEK	8	10	1	0	0	N/A	1	0	0	0	0	8	1
	ANACOSTIA RIVER	9	0	0	0	0	N/A	2	0	0	0	0	0	0
	POTOMAC RIVER (Above D.C.)	10	343	35	224	35	500	10	8	6	12	12	49	8
	TOTAL (206)		366	37	224	35	500	13	8	6	12	12	61	10
	GRAND TOTAL		1,178	188	1,408	171	1,050	30	62	48	44	44	179	30

1/Includes diversion of 26 mgd to Chester.

TABLE C-V-8
FRESHWATER REQUIREMENTS AND CONSUMPTIVE LOSSES BY USE FOR 2020
(MGD)

AREA		INFLOW POINT SUB-AREA	PUBLIC-DOMESTIC-COMM REQ'D	PUBLIC-DOMESTIC-COMM LOSS	MANUFACTURING REQ'D	MANUFACTURING LOSS	POWER REQ'D	POWER LOSS	IRRIGATION REQ'D	IRRIGATION LOSS	LIVESTOCK REQ'D	LIVESTOCK LOSS	MINERALS REQ'D	MINERALS LOSS
204	SUSQUEHANNA RIVER BASIN	15	868 1/	193 1/	290	195	792	528	31	23	24	24	149	29
205	UPPER/LOWER CHESAPEAKE BAY													
	NANSEMOND RIVER	1	130	55 2/	67	49	0	0	1	1	0	0	7	1
	CHICKAHOMINY RIVER	2	12	2	0	0	0	0	0	0	0	0	15	2
	APPOMATTOX RIVER	3	17	2	1	1	25	17	3	2	2	2	5	1
	JAMES RIVER (above Richmond)	4	128	19	265	196	0	0	8	6	0	0	40	5
	YORK RIVER	5	31	5	59	47	67	45	2	2	0	0	3	0
	RAPPAHANNOCK RIVER	6	19	3	55	43	0	0	2	2	1	1	4	1
	PATUXENT RIVER	11	26	4	5	4	0	0	4	3	1	1	10	2
	SEVERN RIVER	12	24	4	12	9	0	0	1	0	0	0	3	0
	PATAPSCO RIVER	13	216	32	349	262	46	31	0	0	2	2	12	2
	GUNPOWDER RIVER	14	23	3	8	6	69	46	4	3	1	1	10	1
	BOHEMIA RIVER	16	7	1	7	5	0	0	8	6	1	1	6	1
	CHESTER RIVER	17	5	1	3	2	0	0	36	27	1	1	0	0
	WYE RIVER	18	0	0	0	0	0	0	0	0	0	0	0	0
	CHOPTANK RIVER	19	10	2	13	10	0	0	81	60	0	0	1	0
	NANTICOKE RIVER	20	22	3	33	25	0	0	6	5	1	1	3	0
	POCOMOKE RIVER	21	9	1	11	9	0	0	11	8	0	0	1	0
	TOTAL (205)		679	137	888	668	207	139	167	125	10	10	120	16
206	POTOMAC RIVER BASIN													
	LOWER POTOMAC (Wicomico)	7	42	4	0	0	0	0	0	0	0	0	15	2
	OCCOQUAN CREEK	8	42	4	0	0	0	0	0	0	0	0	35	5
	ANACOSTIA RIVER	9	0	0	0	0	0	0	0	0	0	0	0	0
	POTOMAC RIVER (Above D.C.)	10	956	98	263	195	170	113	30	23	16	16	198	26
	TOTAL (206)		1,040	106	263	195	170	113	30	23	16	16	248	33
	GRAND TOTAL		2,587	436	1,441	1,058	1,169	780	228	171	50	50	517	78

1/Includes diversion of 57 mgd to Chester.
2/Includes 36 mgd to Atlantic Ocean Sewage Treatment Plant.

Minerals

General. In the mineral industry, water is used mainly in percussion drilling for dust control and, in diamond drilling, to cool and lubricate the bits and remove the cuttings. Water is also used to cool compressors, engines, and condense moisture from compressed air before it is piped to the air powered equipment. The other principal use of water is in separating waste from the product.

Methodology. A comparison of the projections in the NAR Study with those in the National Assessment revealed that the two sets of data were not consistent. It was, therefore, decided to extrapolate the demands and losses in the assessment backwards for each of the 3 ASR's rather than use the data from the NAR Study for the 1965 mineral industry water supply demands.

For the year 2020, the National Assessment figures were projected assumming a direct relationship between "new" water use and constant dollar earnings as compiled from the OBERS Series E projections. These withdrawals and losses were then distributed to the inflow point areas through the use of data from the Susquehanna River Basin Report and the 1964 crushed stone, sand and gravel production figures from the NAR Study. The water withdrawals and consumptive losses associated with the mineral industry for 1965 and 2020 for the 21 hydrologic areas are shown on Tables C-V-7 and C-V-8, respectively.

Summary

As was previously stated, Tables C-V-7 and C-V-8 summarize the average annual water requirements and consumptive losses for each category of water use within each of the 21 sub-areas for the years 1965 and 2020 respectively. Tables C-V-9 and C-V-10 show the total 1965 and 2020 consumptive losses within each sub-area by month. The variance in the monthly figures reflect the changing water requirements for public, domestic, and commercial purposes and the seasonal requirements for irrigation.

EFFECTS OF CONSUMPTIVE LOSSES ON STREAMFLOWS

As stated in the previous section of this chapter, future streamflows were determined by subtracting from the base flows, the incremental increase in consumptive losses projected to the year 2020. In order to show the relative magnitude of these losses to the streamflows, an analysis was made of the 5 major tributaries and the total Bay inflow.

This analysis, as shown on Table C-V-11, shows the magnitude of the increase in consumptive losses as a percent of the monthly flows. This was done for the four years of the drought and also for the long term average monthly flows. As can be seen on the table, the losses are small when compared to the average monthly flows. The maximum percentage occurs in the Potomac River in September when the losses are over 14 percent of the average monthly flow. The maximum for the total Bay is 11 percent and occurs in both June and September.

When compared to the monthly flows of the drought, however, these losses become quite significant. In August of 1966, the projected increases in consumptive losses were greater than 50 percent of the freshwater inflow for the entire basin. In addition, for some of the individual rivers, the projected increases in losses for a given month were greater than the flow of the river. Because these are such a large percentage of drought flows, they will cause substantial alterations in the salinities of the estuary.

TABLE C-V-9
TOTAL CONSUMPTIVE LOSSES BY MONTH FOR 1965
(CFS)

ASR	AREA	INFLOW POINT SUB-AREA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
204	SUSQUEHANNA RIVER BASIN	15	237	229	252	256	302	356	450	407	326	293	265	255	302
205	UPPER/LOWER CHESAPEAKE BAY														
	NANSEMOND RIVER	1	18	17	20	21	26	32	43	37	28	25	21	20	26
	CHICKAHOMINY RIVER	2	2	2	2	2	3	3	4	3	3	3	2	2	3
	APPOMATTOX RIVER	3	14	13	14	14	15	18	22	20	15	14	14	14	14
	JAMES RIVER (above Richmond)	4	49	48	51	51	57	66	83	75	58	54	51	50	58
	YORK RIVER	5	42	42	42	42	43	45	49	47	43	43	42	42	43
	RAPPAHANNOCK RIVER	6	15	15	15	16	17	20	25	22	17	16	16	15	17
	PATUXENT RIVER	11	6	5	6	6	9	14	25	19	7	6	6	6	10
	SEVERN RIVER	12	3	3	3	3	5	7	11	9	5	4	3	3	5
	PATAPSCO RIVER	13	53	51	57	58	66	76	90	83	71	65	58	56	65
	GUNPOWDER RIVER	14	6	6	6	6	9	15	27	21	8	7	6	6	10
	BOHEMIA RIVER	16	4	4	4	4	4	5	7	6	4	4	4	4	4
	CHESTER RIVER	17	2	2	2	2	3	6	13	9	2	2	2	2	4
	WYE RIVER	18	0	0	0	0	0	0	0	0	0	0	0	0	0
	CHOPTANK RIVER	19	2	2	2	2	6	13	26	19	4	3	2	2	7
	NANTICOKE RIVER	20	9	9	10	10	14	23	40	31	12	11	10	10	16
	POCOMOKE RIVER	21	2	2	2	2	20	53	123	87	7	3	2	2	25
	TOTAL (205)		227	221	236	239	297	396	588	488	284	260	239	234	307
206	POTOMAC RIVER BASIN														
	LOWER POTOMAC (Wicomico)	7	3	3	3	3	4	4	5	5	4	4	3	3	4
	OCCOQUAN CREEK	8	4	4	4	4	5	5	6	6	5	5	4	4	5
	ANACOSTIA RIVER	9	3	3	3	3	3	3	3	3	3	3	3	3	3
	POTOMAC RIVER (Above D.C.)	10	133	128	139	140	161	191	245	221	173	154	146	140	164
	TOTAL (206)		143	138	149	150	173	203	259	235	185	166	156	150	176
	GRAND TOTAL		607	588	637	645	772	955	1,297	1,130	795	719	660	639	785

TABLE C-V-10
TOTAL CONSUMPTIVE LOSSES BY MONTH FOR 2020
(CFS)

ASR	AREA	INFLOW POINT SUB-AREA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
204	SUSQUEHANNA RIVER BASIN	15	1,401	1,387	1,429	1,437	1,535	1,655	1,871	1,771	1,571	1,505	1,454	1,434	1,537
205	UPPER/LOWER CHESAPEAKE BAY														
	NANSEMOND RIVER	1	151	149	155	156	165	176	193	184	169	164	156	154	164
	CHICKAHOMINY RIVER	2	5	5	5	5	6	7	8	7	6	6	5	5	6
	APPOMATTOX RIVER	3	35	35	35	35	39	45	58	51	38	37	36	35	40
	JAMES RIVER (above Richmond)	4	329	327	333	334	348	371	412	391	348	341	334	332	350
	YORK RIVER	5	146	146	148	148	152	157	167	162	152	150	148	147	152
	RAPPAHANNOCK RIVER	6	72	72	73	73	76	82	92	87	75	74	73	73	77
	PATUXENT RIVER	11	14	14	15	15	20	28	43	35	19	17	15	15	21
	SEVERN RIVER	12	17	17	18	18	20	24	29	27	21	20	18	18	21
	PATAPSCO RIVER	13	490	487	497	498	512	528	551	540	520	511	499	495	511
	GUNPOWDER RIVER	14	87	86	87	87	92	100	115	108	91	89	87	87	93
	BOHEMIA RIVER	16	12	12	12	12	19	32	59	45	14	12	12	12	21
	CHESTER RIVER	17	5	5	5	6	37	96	224	159	14	6	6	5	47
	WYE RIVER	18	0	0	0	0	0	0	0	0	0	0	0	0	0
	CHOPTANK RIVER	19	17	17	17	17	87	221	506	361	37	18	17	17	111
	NANTICOKE RIVER	20	43	43	44	44	51	63	88	76	48	45	44	44	53
	POCOMOKE RIVER	21	15	15	15	16	25	43	82	62	19	16	16	15	28
	TOTAL (205)		1,438	1,430	1,459	1,464	1,649	1,973	2,627	2,295	1,571	1,506	1,466	1,454	1,695
206	POTOMAC RIVER BASIN														
	LOWER POTOMAC (Wicomico)	7	7	6	8	8	10	12	15	14	12	10	9	8	10
	OCCOQUAN CREEK	8	12	11	12	13	14	16	19	18	16	14	13	13	14
	ANACOSTIA RIVER	9	0	0	0	0	0	0	0	0	0	0	0	0	0
	POTOMAC RIVER (Above D.C.)	10	633	619	649	653	718	813	989	910	745	691	669	652	728
	TOTAL (206)		652	636	669	674	742	841	1,023	942	773	715	691	673	752
	GRAND TOTAL		3,491	3,453	3,557	3,575	3,926	4,469	5,521	5,008	3,915	3,726	3,611	3,561	3,984

TABLE C-V-11

RELATIONSHIP OF INCREASES IN CONSUMPTIVE LOSSES TO MONTHLY INFLOWS FOR MAJOR TRIBUTARIES

Month	Incremental Increase in Consumptive Loss 1965 to 2020 (cfs)	Percentage of Average Monthly Inflow 1963	1964	1965	1966	Long Term Average
		Susquehanna River				
Jan	1164	5.0	2.4	5.8	6.1	2.8
Feb	1158	6.8	3.7	2.4	2.0	2.5
Mar	1177	1.1	0.8	2.6	1.4	1.3
Apr	1181	2.1	1.5	1.9	3.2	1.4
May	1233	3.6	2.4	4.0	2.0	2.3
Jun	1299	6.4	11.3	12.3	7.4	4.2
Jul	1421	18.3	22.2	33.4	28.8	8.0
Aug	1364	26.5	28.3	28.4	35.3	9.8
Sep	1245	28.5	50.4	25.6	23.3	10.0
Oct	1212	42.0	38.5	11.1	19.3	6.9
Nov	1189	16.9	36.2	10.1	9.8	4.1
Dec	1179	5.9	13.0	7.0	3.6	3.1
		Potomac River				
Jan	500	4.8	2.7	3.3	28.8	3.7
Feb	491	8.5	3.9	2.5	3.6	2.8
Mar	510	1.1	1.7	1.8	4.1	2.2
Apr	513	6.1	2.8	3.0	4.3	2.7
May	557	11.1	3.6	7.0	4.0	3.9
Jun	622	8.8	21.2	23.8	24.0	6.4
Jul	744	37.2	32.0	51.4	104.6	13.7
Aug	689	49.5	56.6	59.0	126.2	13.1
Sep	572	51.3	70.9	55.2	9.8	14.2
Oct	537	58.5	22.5	32.9	8.1	9.6
Nov	523	18.3	26.0	47.3	13.6	8.5
Dec	512	11.3	9.0	48.8	6.4	5.2

TABLE C-V-11 (Cont'd)

RELATIONSHIP OF INCREASES IN CONSUMPTIVE LOSSES TO MONTHLY INFLOWS FOR MAJOR TRIBUTARIES

Month	Incremental Increase in Consumptive Loss 1965 to 2020 (cfs)	Percentage of Average Monthly Inflow 1963	1964	1965	1966	Long Term Average
		Rappahannock River				
Jan	57	1.5	1.1	1.8	10.8	1.5
Feb	57	2.3	1.3	0.9	1.4	1.3
Mar	58	0.7	1.7	1.0	2.1	1.3
Apr	57	2.9	1.4	2.5	2.9	1.3
May	59	5.3	2.2	4.0	1.8	1.7
Jun	62	2.6	8.7	8.0	6.5	2.4
Jul	67	20.1	11.0	10.8	25.3	4.0
Aug	65	52.4	19.8	18.5	47.1	3.2
Sep	58	40.8	24.6	19.1	1.8	3.8
Oct	58	37.2	6.6	12.4	1.9	2.9
Nov	57	5.3	5.4	15.6	3.8	2.6
Dec	58	5.1	3.0	14.9	2.5	2.0
		York River				
Jan	104	2.6	2.6	3.6	16.2	2.9
Feb	104	3.7	1.6	2.6	2.8	2.5
Mar	106	1.2	3.1	2.1	4.0	2.2
Apr	106	5.2	3.2	3.5	7.4	2.8
May	109	9.5	6.2	8.4	5.6	4.0
Jun	112	3.2	16.8	11.0	16.3	5.7
Jul	118	37.0	17.7	13.6	43.1	7.8
Aug	115	64.3	18.7	23.4	67.6	6.5
Sep	109	50.0	22.1	29.5	8.6	11.0
Oct	107	48.2	11.9	29.0	4.4	6.9
Nov	106	9.5	11.5	28.3	10.6	5.1
Dec	105	6.3	5.1	24.0	7.1	3.4

TABLE C-V-11 (Cont'd)

RELATIONSHIP OF INCREASES IN CONSUMPTIVE LOSSES TO MONTHLY INFLOWS FOR MAJOR TRIBUTARIES

Month	Incremental Increase in Consumptive Loss 1965 to 2020 (cfs)	Percentage of Average Monthly Inflow 1963	1964	1965	1966	Long Term Average
		James River				
Jan	280	2.6	2.4	2.9	17.5	2.7
Feb	279	4.7	2.2	1.8	2.4	2.3
Mar	282	1.1	2.1	1.9	3.2	2.0
Apr	283	5.5	3.5	2.9	7.5	2.3
May	291	8.1	6.1	5.2	3.6	3.4
Jun	305	10.3	17.0	12.5	13.8	4.5
Jul	329	25.8	22.7	18.7	47.4	7.5
Aug	316	34.9	34.1	26.1	35.6	6.0
Sep	290	34.1	26.4	27.3	9.3	8.0
Oct	287	30.9	13.1	15.4	4.0	6.3
Nov	283	14.3	10.8	21.7	7.3	5.7
Dec	282	9.3	5.1	24.1	5.0	3.6
		Total Bay				
Jan	2,884	4.4	2.6	4.6	10.8	3.2
Feb	2,865	6.0	3.1	2.7	2.7	2.7
Mar	2,918	1.2	1.4	2.4	2.4	1.9
Apr	2,930	3.6	2.2	2.8	4.5	2.1
May	3,154	6.2	3.7	6.0	3.2	3.4
Jun	3,474	7.3	16.6	16.6	12.0	5.6
Jul	4,224	30.6	29.2	32.4	48.7	11.0
Aug	3,878	38.0	37.5	32.8	56.9	10.3
Sep	3,120	35.4	38.9	30.8	12.8	11.0
Oct	3,007	44.3	22.2	16.9	8.5	8.0
Nov	3,031	14.1	22.3	17.9	11.3	5.6
Dec	2,922	7.6	9.2	13.4	5.1	3.9

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CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY

APPENDIX D

HYDRAULIC MODEL TEST

Department of the Army
Baltimore District, Corps of Engineers
Baltimore, Maryland
September 1984

FOREWORD

This is one of the volumes comprising the final report on the Corps of Engineers' Chesapeake Bay Study. The report represents the culmination of many years of study of the Bay and its associated social, economic, and environmental processes and resources. The overall study was done in three distinct developmental phases. A description is provided below of each study phase, followed by a description of the organization of the report.

The initial phase of the overall program involved the inventory and assessment of the existing physical, economic, social, biological, and environmental conditions of the Bay. The results of this effort were published in a seven volume document titled Chesapeake Bay Existing Conditions Report, released in 1973. This was the first publication to present a comprehensive survey of the tidal Chesapeake and its resources as a single entity.

The second phase of the program focused on projection of water resource requirements in the Bay Region for the year 2020. Completed in 1977, the Chesapeake Bay Future Conditions Report documents the results of that work. The 12-volume report contains projections for resource categories such as navigation, recreation, water supply, water quality, and land use. Also presented are assessments of the capacities of the Bay system to meet the identified future requirements, and an identification of problems and conflicts that may occur with unrestrained growth in the future.

In the third and final study phase, two resource problems of particular concern in Chesapeake Bay were addressed in detail: low freshwater inflow and tidal flooding. In the Low Freshwater Inflow Study, results of testing on the Chesapeake Bay Hydraulic Model were used to assess the effects on the Bay of projected future depressed freshwater inflows. Physical and biological changes were quantified and used in assessments of potential social, economic, and environmental impacts. The Tidal Flooding Study included development of preliminary stage-damage relationships and identification of Bay communities in which structural and nonstructural measures could be beneficial.

The final report of the Chesapeake Bay Study is composed of three major elements: (1) Summary, (2) Low Freshwater Inflow Study, and (3) Tidal Flooding Study. The Chesapeake Bay Study Summary Report includes a description of the results, findings, and recommendations of all the above described phases of the Chesapeake Bay Study. It is incorporated in four parts:

Summary Report
Supplement A -- Problem Identification
Supplement B — Public Involvement
Supplement C — Hydraulic Model

The Low Freshwater Inflow Study consists of a Main Report and six supporting appendices. The report includes:

Main Report
Appendix A -- Problem Identification
Appendix B — Plan Formulation
Appendix C — Hydrology
Appendix D — Hydraulic Model Test

Appendix E -- Biota
Appendix F — Map Folio

The Tidal Flooding Study consists similarly of a Main Report and six appendices. The report includes:

Main Report
Appendix A -- Problem Identification
Appendix B -- Plan Formulation, Assessment, and Evaluation
Appendix C -- Recreation and Natural Resources
Appendix D -- Social and Cultural Resources
Appendix E -- Engineering, Design, and Cost Estimates
Appendix F -- Economics

CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY

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HYDRAULIC MODEL TEST

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CHAPTER I

THE CHESAPEAKE BAY MODEL

INTRODUCTION

One of the more important elements of the Low Freshwater Inflow Study was the determination of how the salinities of Chesapeake Bay changed as a function of variations in freshwater inflow. But, the physical characteristics of the Bay are extremely complex and cannot be fully addressed analytically. Particularly troublesome are the three dimensional aspects of salinity. Not only is the Chesapeake saltier at the bottom than at the surface, but, there are distinct changes in both lateral and longit ıı .ıal salinities. All of this is controlled by the interactions of freshwater inflow, salt water from the ocean and tides. At the present time, the only way this salinity regime can be simulated is through the use of the Chesapeake Bay Model.

The Chesapeake Bay Model is located at Matapeake, Maryland on a 60 acre tract of land donated by the State of Maryland (See Figure D-I-1). The site is on the Delmarva Peninsula, along Maryland Route 8 and approximately 3 miles south of the eastern terminus of the William Preston Lane Memorial Bridge (Chesapeake Bay Bridge). It is within commuting distance of over 3,000,000 people being less than 50 miles from both Washington, D.C. and Baltimore, Maryland.

DESCRIPTION OF MODEL

Model Limits and Scale

The Chesapeake Bay Model is the largest estuarine model in the world. It is a fixed bed, geometrically distorted model, hand molded in concrete. Included within its 8 acre area is Chesapeake Bay and all of its tributaries to the head of tide (See Figure D-I-2). It is built to scales of 1 to 1000 horizontally, and 1 to 100 vertically. These scales, in conjunction with the "model laws" determine other model scale ratios. These are :

Characteristic	Ratio
Depth	1:100
Length	1:1000
Time	1:100
Velocity	1:10
Discharge	1:1,000,000
Volume	1:100,000,000
Slope	10:1

The time ratio of 1:100 means that one year in Chesapeake Bay can be reproduced in the model in 3.65 days or, a 12 hour and 25 minute tidal cycle in 7.45 minutes.

Model Appurtances

The model complex was designed to operate as a self contained unit. Water treatment facilities, manual and computer activated model controls, as well as automated data

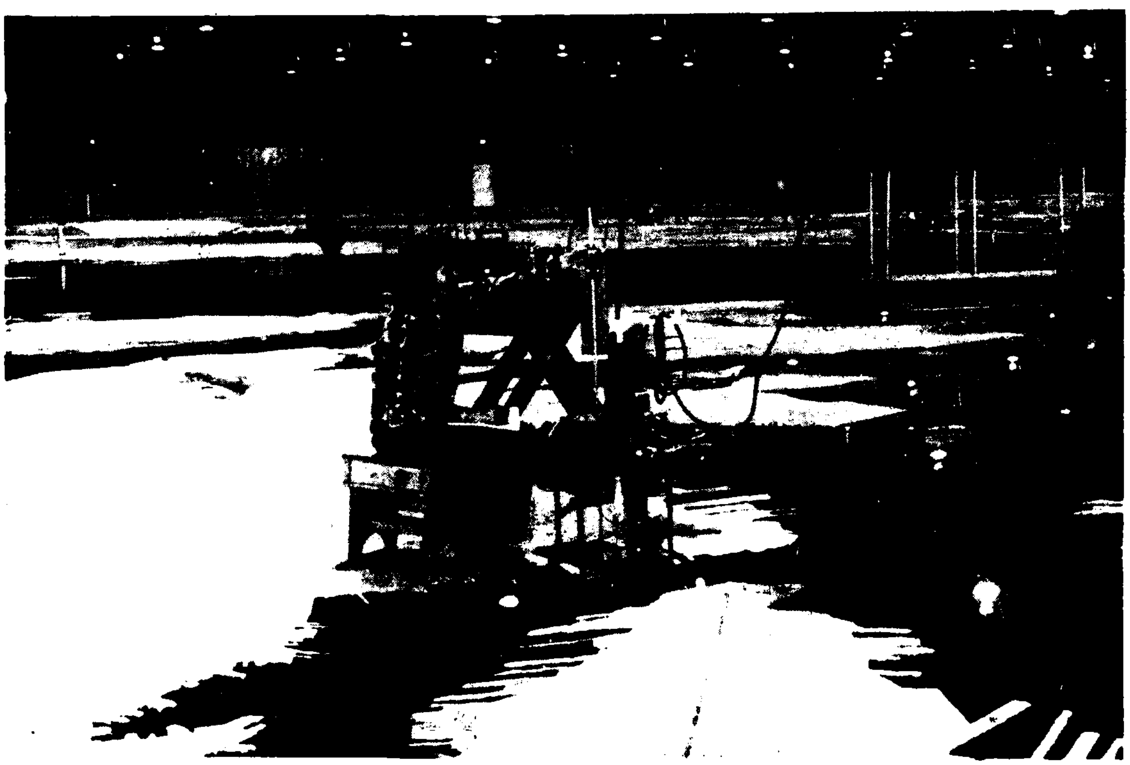


FIGURE D-I-1 CHESAPEAKE BAY HYDRAULIC MODEL AND SHELTER

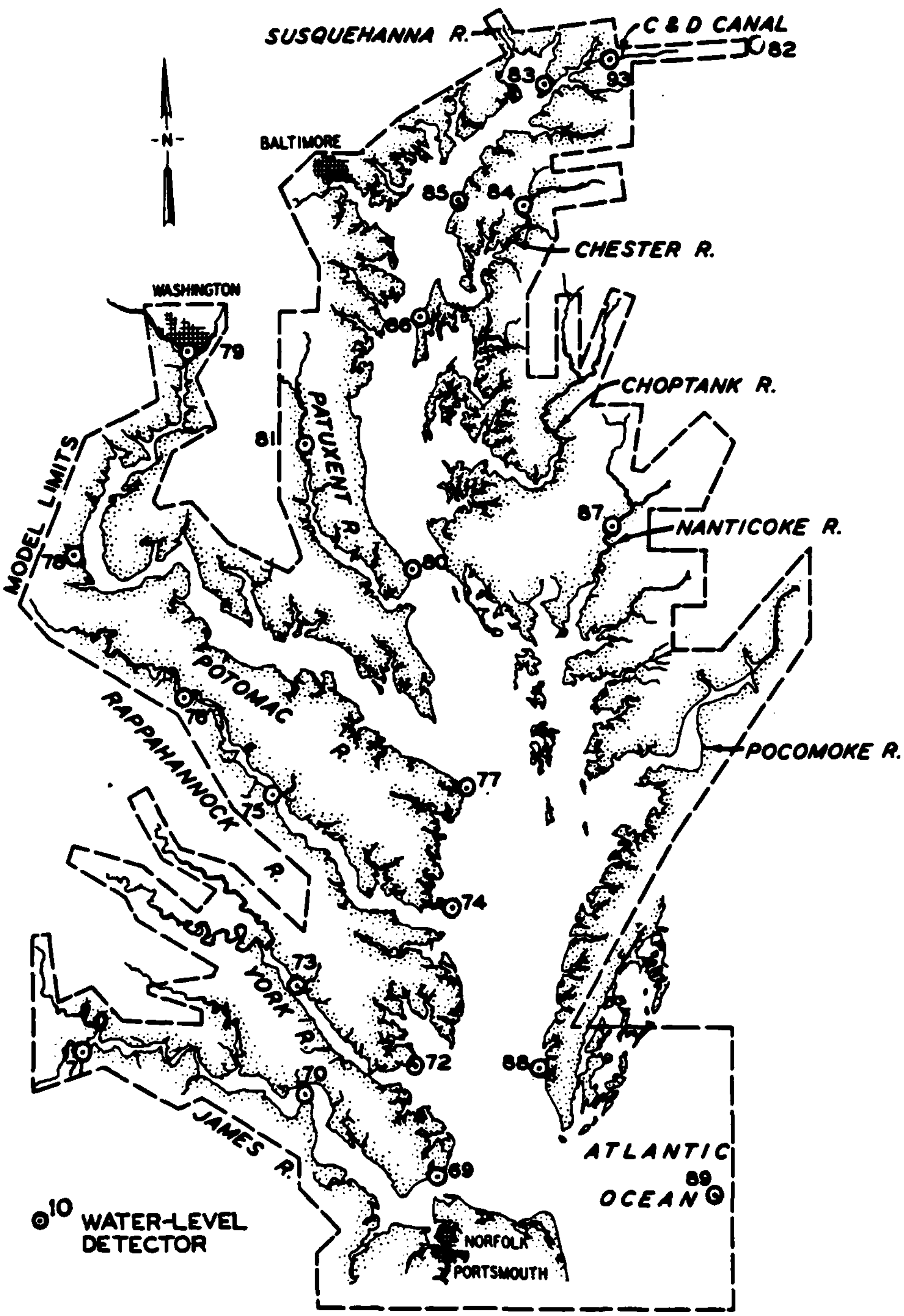


FIGURE D-I-2 CHESAPEAKE BAY MODEL LIMITS

aquisition systems and emergency power supplies were incorporated in its design and construction. Laboratory facilities were provided for analysis of salinity and dye concentrations of water samples. The primary appurtances are described below.

Computer Facilities Two computers were used to control the model and collect data. This system automatically operated the tide generators and freshwater inflow devices. In turn monitoring devices transmitted water surface elevation and freshwater inflow volumes to the computer for real time monitoring, storage, modification and management.

Freshwater Inflow Control System Programmable freshwater inflow control devices capable of reproducing variable hydrographs were located at 21 strategically selected inflow points on the model (See Figure D-I-3). A total of 256 discrete flow rates could be obtained from each inflow device by energizing different combinations of solenoid valves. Valves of two sizes were used to produce a flow ranging from the smallest measurable one to the maximum discharge from an individual tributary. The magnitude of discharge from these digital valves is controlled by the computers.

Water Supply System - The water system is comprised of two deep wells, a treatment plant to remove the iron and manganese from the water and an elevated storage tank. The discharge capability of the wells is 250 and 500 gpm respectively. The water treatment plant had a rated capacity of 750 gpm while the elevated tank could store 400,000 gal. An extensive pipe system distributed the water to various points on the model.

Tide Generators The primary tide generator for the model is a constant head, gravity feed inflow - outflow system. It is comprised of an elevated supply sump, a head bay area and a return sump (See Figure D-I-4). The supply sump discharges water to the head bay area to simulate the flooding of the tide. To simulate the ebb of the tide, water is allowed to flow from the model to the return sump. The volumes of water flow are controlled by two rolling gate valves. A much smaller secondary tide generator, serving the Chesapeake and Delaware Canal operates on these same principles.

Both the primary and secondary tide generator can be operated by an electro-mechanical control or by the computer. Under computer control, the system is capable of producing a variety of tides, including variable ones. Under electro-mechanical control, only a repetitive 24.84 hour tidal cycle can be produced.

Saltwater Supply System Constant ocean salinity was controlled by maintaining a prescribed concentration of salinity in the supply sump. Saturated brine was obtained by mixing granular salt and water. The brine was injected into the model in the return sump to obtain a desired salinity. This well-mixed solution was then pumped to the supply sump for input to the model.

Induced Mixing Bubbler System A bubbler system was installed in the model to provide additional vertical mixing. The system consisted of a compressor supplying air through tubing placed along the axis of the Bay and major tributaries.

Tide Gages Permanently mounted point gages were installed in the model to correspond to the 75 prototype tide stations shown in Figure D-I-5. These gages, graduated to 0.001 ft (0.1 ft prototype), were used for the manual measurement of tidal elevations.

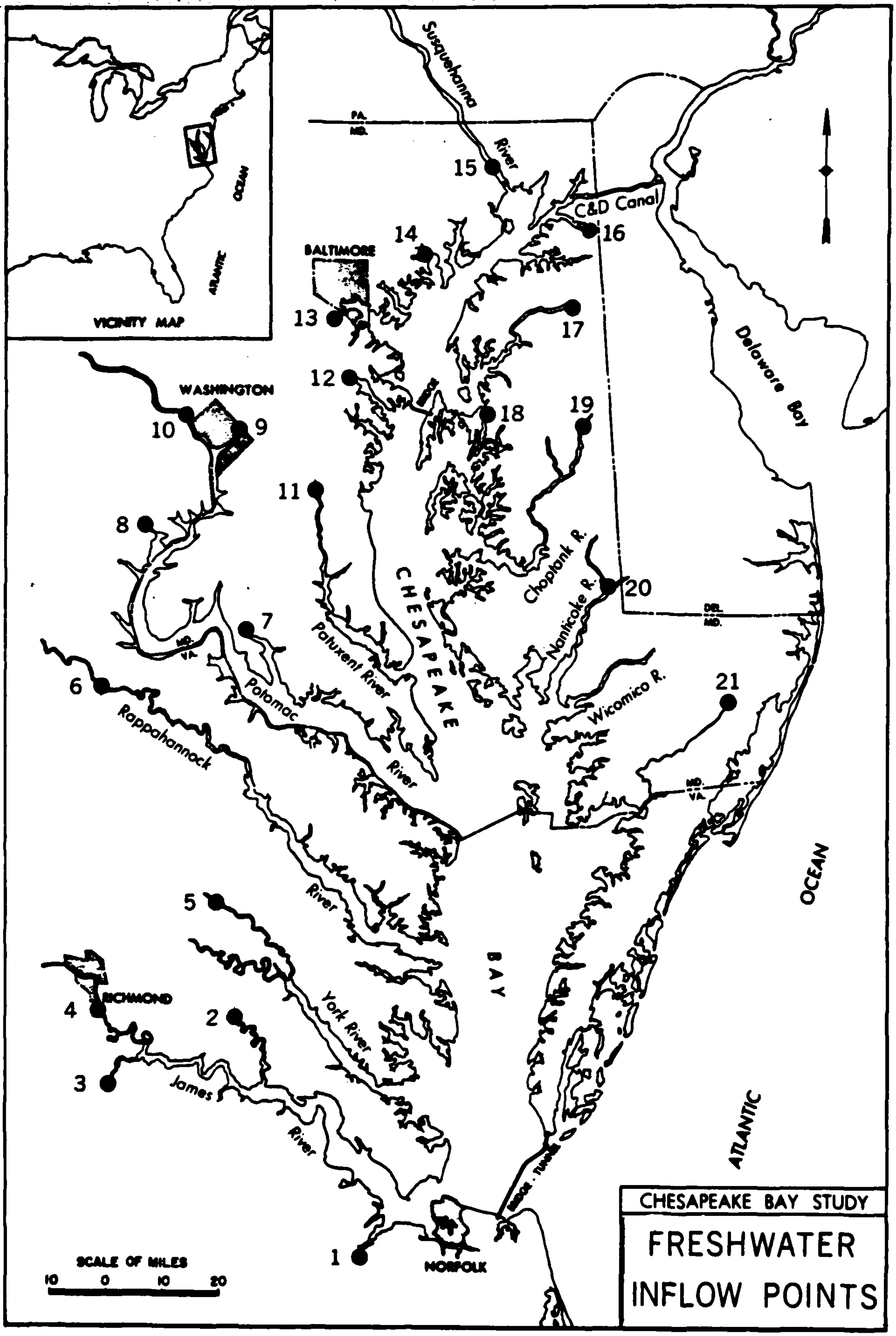


FIGURE D-I-3 FRESHWATER INFLOW POINTS

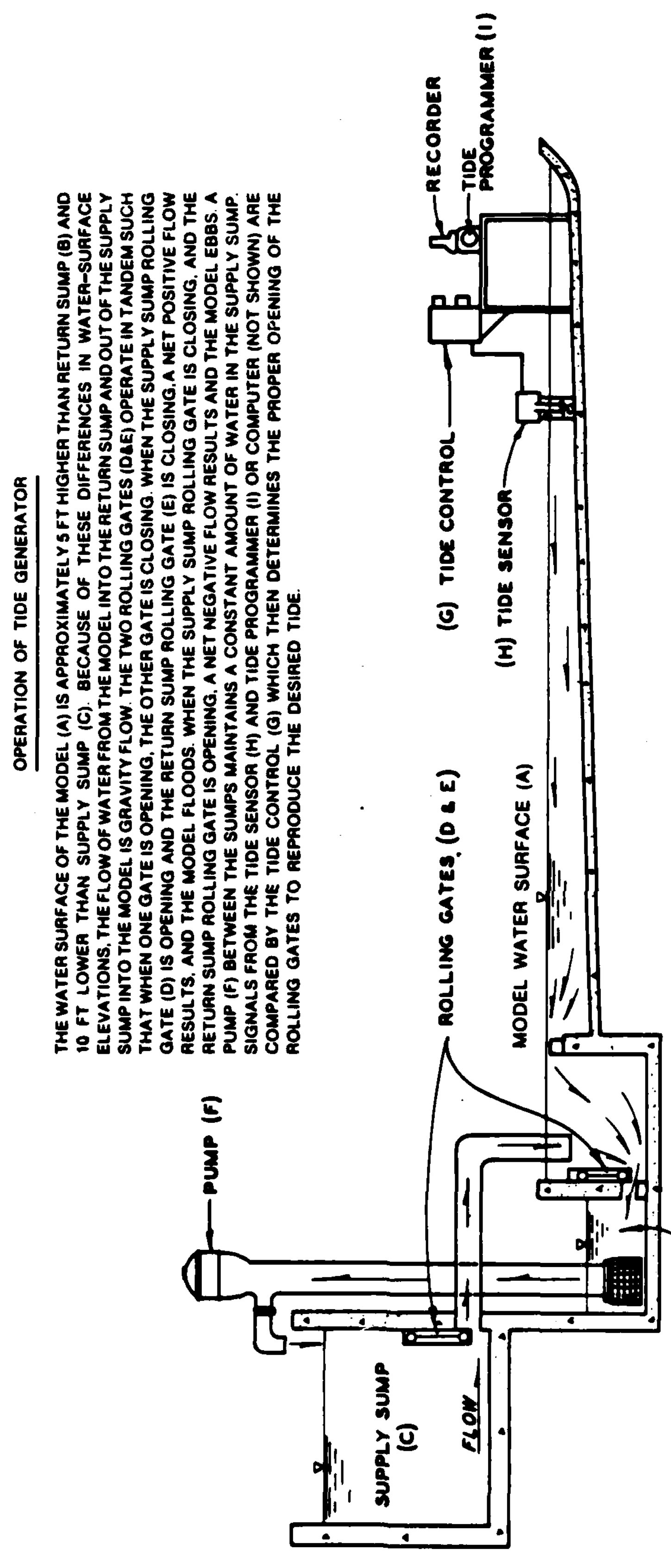


FIGURE D-I-4 PRIMARY TIDE GENERATOR

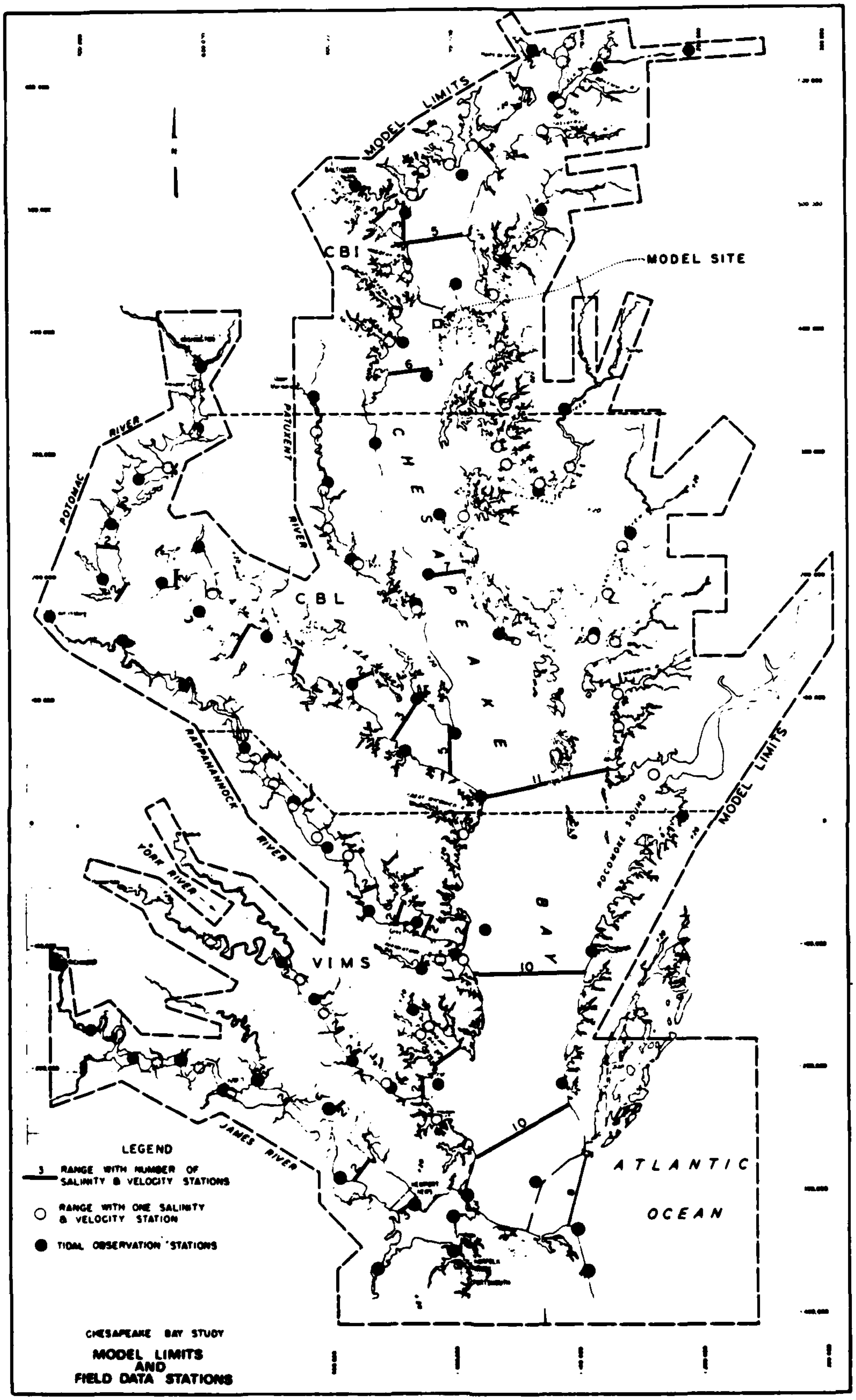


FIGURE D-I-5 LOCATION OF PROTOTYPE TIDAL STATIONS

Water Level Detectors Twenty-two automatic water-level measuring instruments, built at the Waterways Experiment Station, were installed on the model. Sensors detected the changes in water surface elevation and transmitted them to the computer. A diagram of a typical installation of the water level detecting equipment is shown in Figure D-I-6.

Current Velocity Meters Current velocity measurements were made on the model using miniature Price-type current meters (Figure D-I-7). Velocities were obtained by counting the number of revolutions the meter wheel made in a 10-sec interval. The meters were calibrated frequently to ensure an accuracy of ±0.05 fps (0.5 fps prototype).

Salinity and Dye Sampling Salinity and dye samples were taken from the model through use of a vacuum system. There were three independent parts to the system, each designed to sample approximately one-third of the model. Samples were drawn by activating the vacuum system at specified times during the model test. The samples were taken to the laboratory for analysis.

Model Capabilities

There are six basic measurements that are made on estuarine hydraulic models. These include water surface elevation, salinity, current velocity, dye concentration, temperature, and sediment distribution. These measurements can effectively describe the physical impact on an estuarine resource of many of the works of man. Often biological stress can be predicted from the knowledge of changing physical parameters.

Based on the testing conducted, the capability of the Chesapeake Bay Model to reproduce physical prototype data is generally as follows:

a. Water surface elevation could be measured to 0.001 foot in the model, representing 0.1 foot in the prototype.

b. Current velocity could be measured within ±0.03 foot per second. This represented 0.3 foot per second in the prototype. Verification procedures indicated that model velocities may vary up to 20 percent from that in the prototype.

c. Salinity was measured in the model to the same accuracy as in the prototype. Most samples can be relied upon to be accurate within 0.5 ppt.

d. Dye concentration, from dye dispersion tests, was measured by fluorometric methods to 1.0 ppb. The model can be used to predict the distribution and concentration of conservative water quality constituents to an accuracy of about 20 percent.

e. Temperature could be measured to an accuracy of about plus or minus 0.1 degrees Celsius.

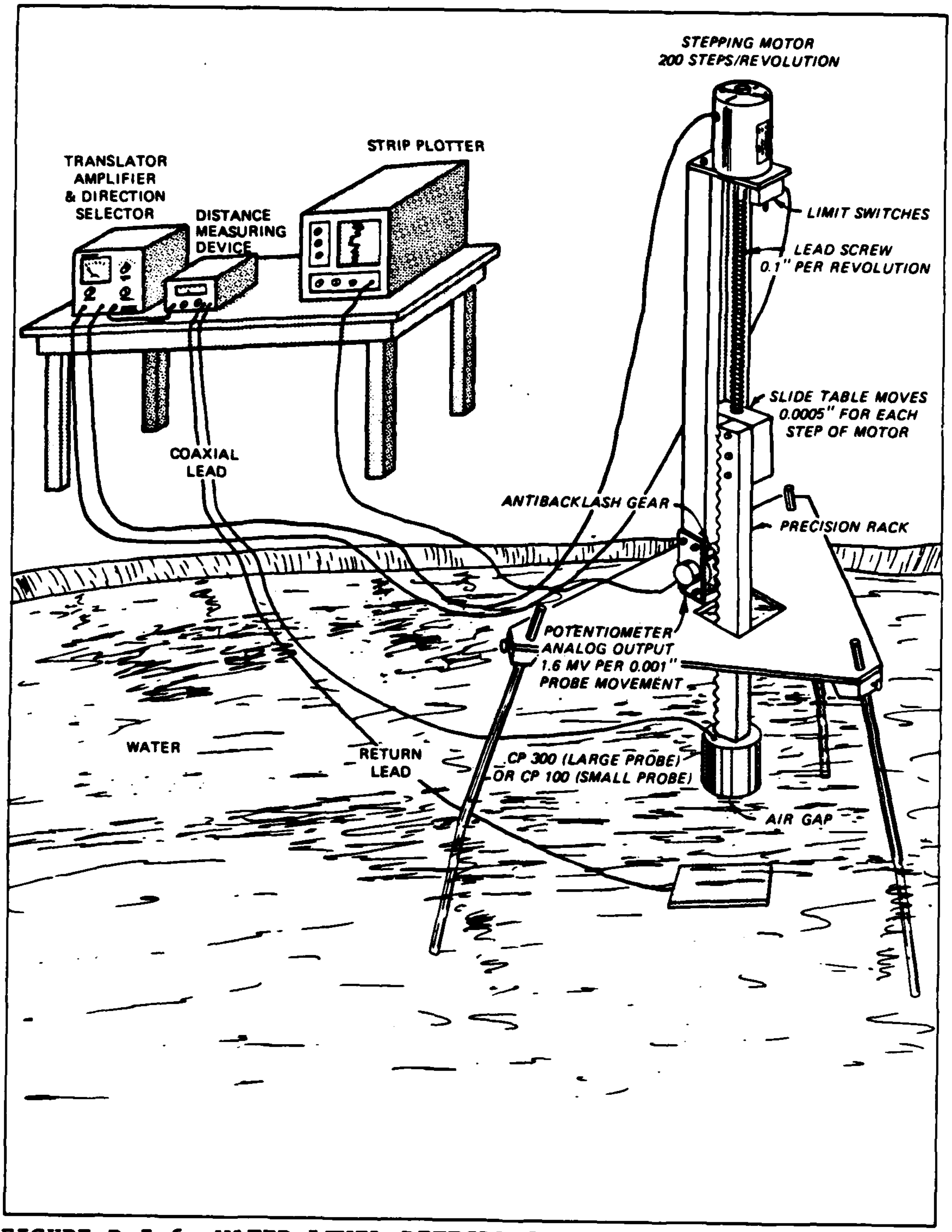


FIGURE D-I-6 WATER-LEVEL DETECTING INSTRUMENT

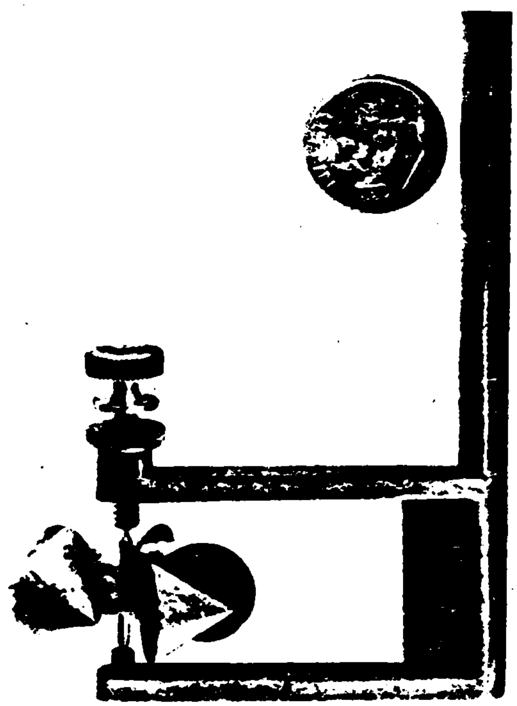


FIGURE D-I-7 MINATURE PRICE-TYPE CURRENT METER

CHAPTER II

TEST DESCRIPTION

DESCRIPTION AND OBJECTIVE OF TESTING

The Low Freshwater Inflow Problem Identification Test provided information on the changes of water surface elevations, velocities and salinity patterns that may occur in the Bay as a result of reductions in freshwater inflow.

The following objectives were established for the Problem Identification Test:

1. To define salinity patterns throughout the Bay and its tidal tributaries resulting from both long term average freshwater inflows and periods of drought, both historical and projected.

2. To define the time it takes for Bay salinities to return to "normal" following a drought condition.

In order to accomplish these objectives, the test was divided into two parts; a base test and a futures test. The freshwater inflows that occurred during the 1963 - 1966 drought were simulated during the base test. The drought was followed by several repetitions of an average inflow year.

In the futures test, both the drought and the long term average inflows were reduced by an amount equivalent to the increases in consumptive losses between 1965 and 2020. By comparing the data between the two tests, the effects of consumptive losses on salinities could be determined. Also the effect of the drought could be determined by comparing drought salinities with average ones. The test conditions are referred to in the remainder of this report as follows:

Base Average - Long term average freshwater inflows

Future Average - Base Average inflows reduced by the increases in consumptive losses expected between the year 1965 and 2020.

Base Drought - The freshwater inflows which occurred between the years 1963 and 1966.

Future Drought - Base Drought inflows reduced by the increases in consumptive losses expected between the years 1965 and 2020.

MODEL TEST CONDITIONS

Model Geometry

For the most part, the configuration of the model reflected the geometry of the prototype. The navigation channels into Baltimore, however were at the authorized 50 foot depth rather than the existing 42 foot depth.

Tidal Conditions

The simulated tide (source tide) generated in the model ocean and imposed on the mouth of Chesapeake Bay was "constructed" from tidal elevation data collected at Old Point Comfort, Virginia. It is described as a 28 lunar day, 56 cycle tide sequence. This tide sequence, shown on Figure D-II-1 was repeated throughout the test.

The Chesapeake and Delaware Canal

The C&D Canal portion of the model was not used during this test for two reasons. First, the focus of the study was on the relationship between salinity and freshwater inflow from the Bay's tributaries. Operation of the canal may have masked this relationship. Second the interchange of water between the Chesapeake and Delaware Bays is not presently known and therefore could not be simulated on the model.

Freshwater Inflows

The hydrographs of freshwater inflows into the model were simulated at the 21 inflow points shown on Figure D-I-3. The sum of the discharges from the 21 points simulated the total freshwater inflow into the estuarine system from the Chesapeake Bay drainage basin. These hydrographs are shown on Plates D-1 through D-22.

Both the 1963-1966 historic drought and the long term average freshwater inflows were simulated on the model by "stepping" the hydrograph in weekly increments. The synthetic long term average hydrograph was constructed in a manner to insure that the long term average salinity regime in Chesapeake Bay would be reproduced in the model. This hydrograph was developed from the long term flow record. It considers both the time history and magnitude of freshwater flows into the estuarine system.

Wastewater Treatment Plants

Discharges from wastewater treatment plants were modeled at eight locations during the base test and 13 locations during the futures test. These are shown on Figure D-II-2. The increase in the number of plants simulated reflects proposed plants that will be operational by the year 2020. In areas where there were several small plants located in close proximity, the discharges were accumulated and simulated in the model at one point. The quantity of water discharged at each point, is also shown on Figure D-II-2. It was simulated as a constant throughout each test except for the Blue Plains Plant on the Potomac River during the futures test. In this case, since the demand for Washington, D.C. exceeded all existing supplies including the total flow of the Potomac River, the discharge of the treatment plant had to be varied.

Modifications to Freshwater Inflows - For the most part, both the Base Drought and Base Average hydrographs, as well as the discharges from the wastewater treatment plants simulated the freshwater inflows as they actually occurred. However, both the Base and Future Drought inflows were modified to reflect the flow regulation provided by the Raystown Dam in the Susquehanna River Basin, the Bloomington Dam in the Potomac River Basin and the Gathright Dam in the James River Basin.

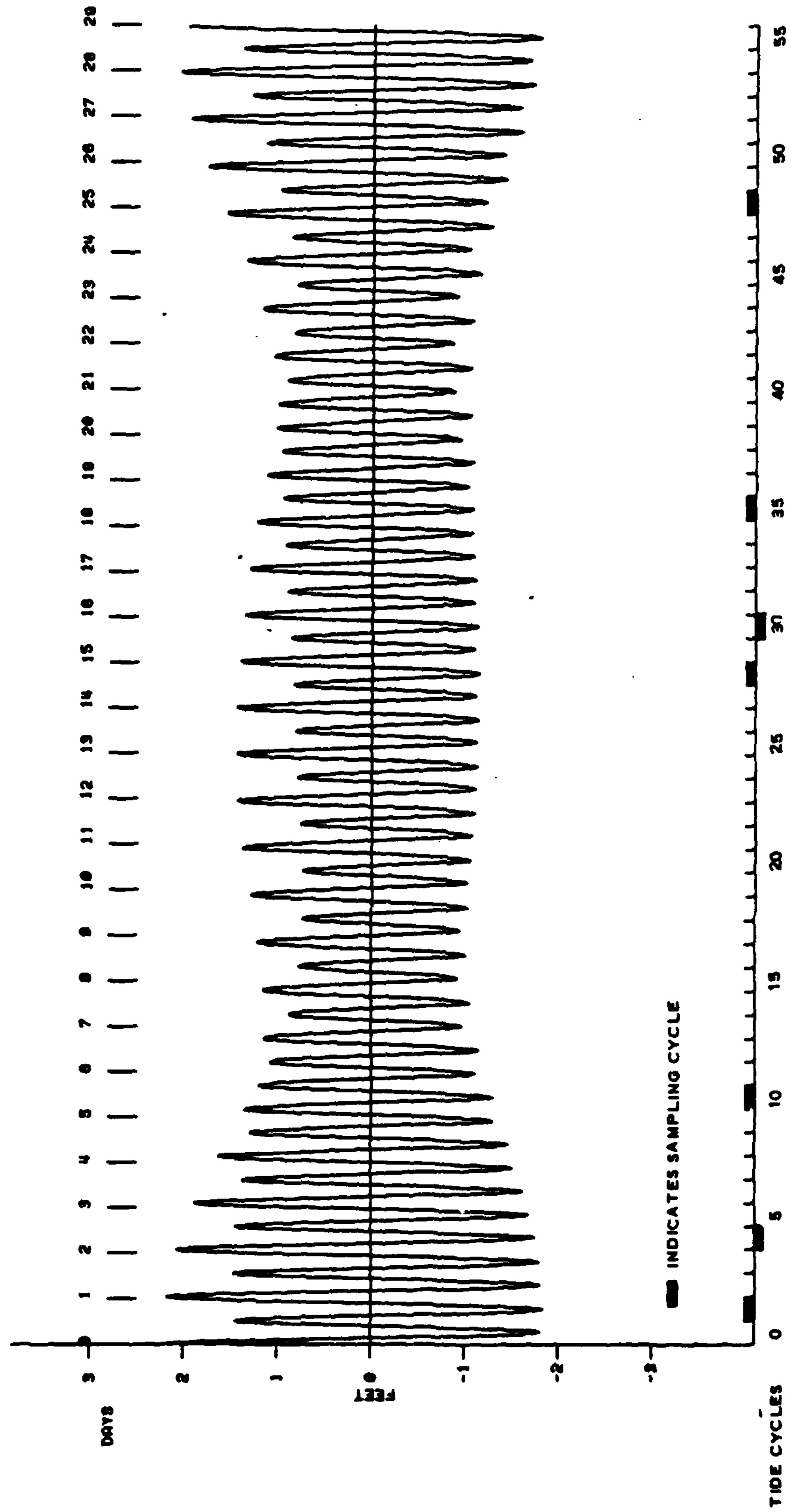
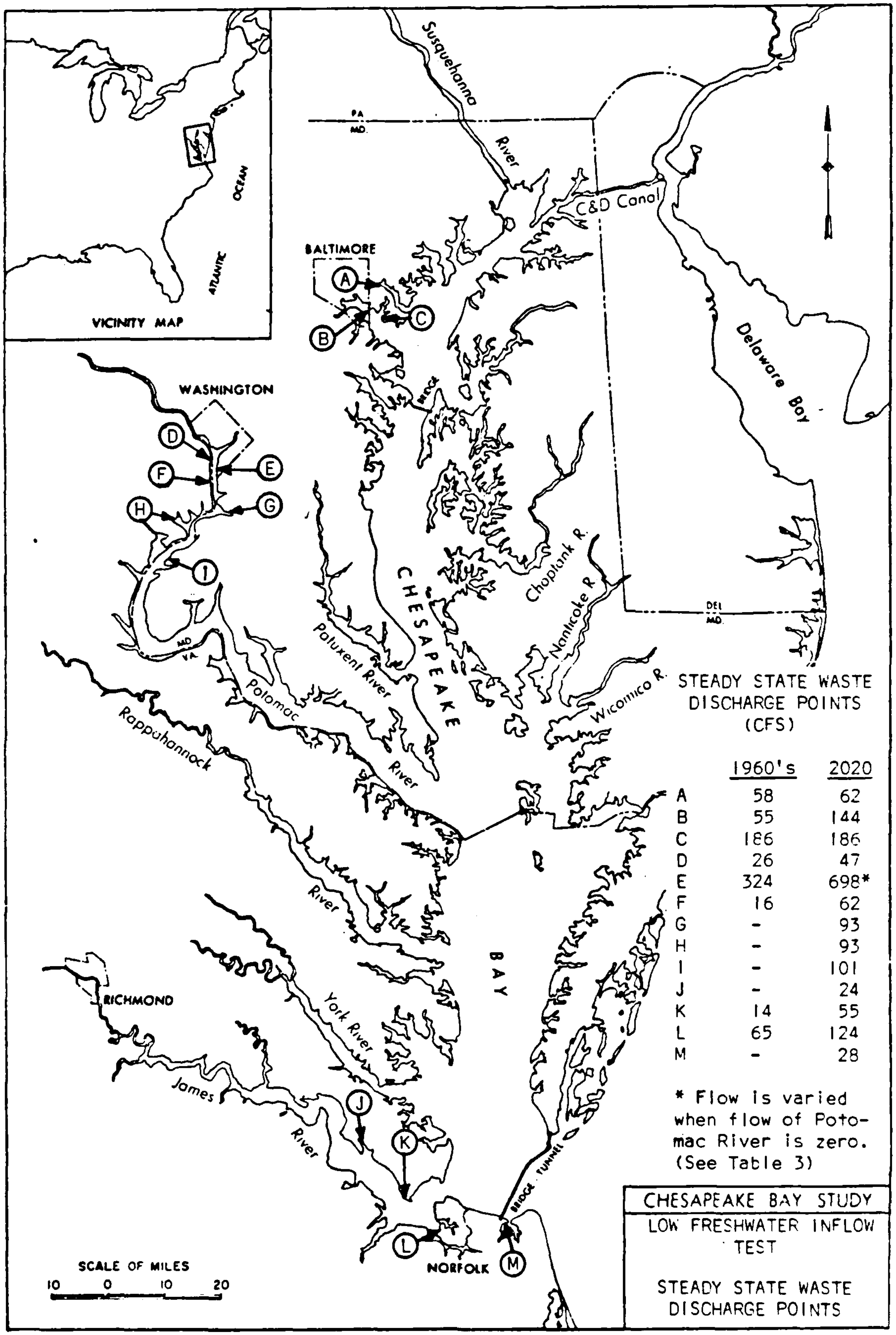


FIGURE D-II-1 OCEAN SOURCE TIDE



	1960's	2020
A	58	62
B	55	144
C	186	186
D	26	47
E	324	698*
F	16	62
G	-	93
H	-	93
I	-	101
J	-	24
K	14	55
L	65	124
M	-	28

FIGURE D-II-2 STEADY STATE WASTE DISCHARGE POINTS

Several other adjustments were made to the hydrograph for both the Future Average and Drought hydrographs. Generally, these reflected:

- Withdrawals of water from the riverine trbutaries with subsequent discharge through wastewater treatment plants located adjacent to the estuary.

- Import of water from outside the Chesapeake Bay drainage basin.

- Additions to the surface waters to reflect the water supply furnished through the use of deep wells.

The following are the specific flow modifications made to the Future Drought and Average freshwater inflows.

- Freshwater inflow at point No. 1 (Nansemond River) was decreased and the discharges of the wastewater treatment plants on the Elizabeth and Lynnhaven rivers were increased to reflect a future water supply diversion to the Norfolk - Portsmouth area.

- Wastewater discharges from the treatment plants located on the Elizabeth and Lynnhaven Rivers were also increased to allow for a 57 mgd importation of water from outside the Chesapeake Bay drainage basin.

- Freshwater inflow at point No. 2 (Chickahominy River) was decreased and the discharge of the wastewater treatment plants on the James River were increased to reflect a future water supply diversion to the Newport News area.

- Freshwater inflows at point 8, 10 and 11 were decreased and the discharges from the wastewater treatment plants on the Potomac and Patuxent Rivers were increased to reflect future water supply diversions to the Washington Metropolitan Area. (The wastewater treatment plant discharges for the Patuxent River were included with the freshwater inflows of Point 11).

- Wastewater discharges from plants in both the Patapsco and Back Rivers were increased to reflect the estimated 250 mgd diversion from the Susquehanna River to the Baltimore area.

- Freshwater inflow at point 14 was decreased and the discharges from the wastewater treatment plants located on the Patapsco and Back Rivers were increased to reflect a water supply diversion to the Baltimore Metropolitan area.

- Freshwater inflows at points 12, 16, 17 and 19 were increased to reflect future increases in the use of groundwater for water supply purposes.

<u>Ocean Source Salinity</u>

The model ocean salinity was maintained within acceptable limits of the desired 32.5 ppt throughout both the base and futures testing.

DATA COLLECTION

During the above testing, tidal elevations, salinities, and velocities were collected at various locations. A more detailed description of data collection procedures is provided below.

Tidal Elevations

Tidal elevations were recorded at 22 locations as shown on Figure D-II-3. The data were collected every 36 seconds, equivalent to 1 hour of real time, using automated water level detectors.

Current Velocities

Current velocities were recorded during both the base and future tests at the 16 stations shown on Figure D-II-4. Measurements were taken at from one to three depths on one spring and one neap tide. During the drought, readings were taken twice; once during a high flow period (April 1965) and once during a low flow period (June 1965). Readings were taken only once during the long term average portion of the test (April). Data were obtained at hourly intervals over a tidal cycle.

Salinities

Salinity samples were collected at the stations shown on Figure D-II-5 and the depths shown on Table D-II-1. Readings were taken at slack before ebb on tides 1, 10, 28, and 48 during each 28-lunar day cycle and on slack before flood once each season for each year. Salinity sampling periods are noted on Figure D-II-1.

CONDUCT OF TEST

Following the establishment of a stable salinity regime on the model using steady state freshwater inflow and a repetitive non-varying tide, the dynamic operating conditions of the model were established. This was done by imposing the 28-lunar day varying tide and the reproduction of the 1963 drought hydrograph, stepped on a weekly basis, on the hydraulic model. In order to verify that the model was accurately reproducing prototype salinity for the corresponding time period, flow regulating characteristics of the major dams were not included in the hydrograph. Salinity distribution in the model during this lead-in condition was monitored at 19 strategically located sampling stations to ensure minimal deviation between both base and future salinity regimes.

During the second half of water year 1963, the historical hydrograph was modified to include the influence of the major dams. In addition, salinity sampling on a model wide basis was initiated. Actual testing began on October 1, 1963, and continued through 28 September 1966, at which time the long term average hydrograph immediately began. This hydrograph was repeated four times to ensure that the model had returned to a "normal" state.

The lead-in conditions for the futures test were identical to the base test. Beginning in the second half of water year 1963, the inflows for the futures test were adjusted not

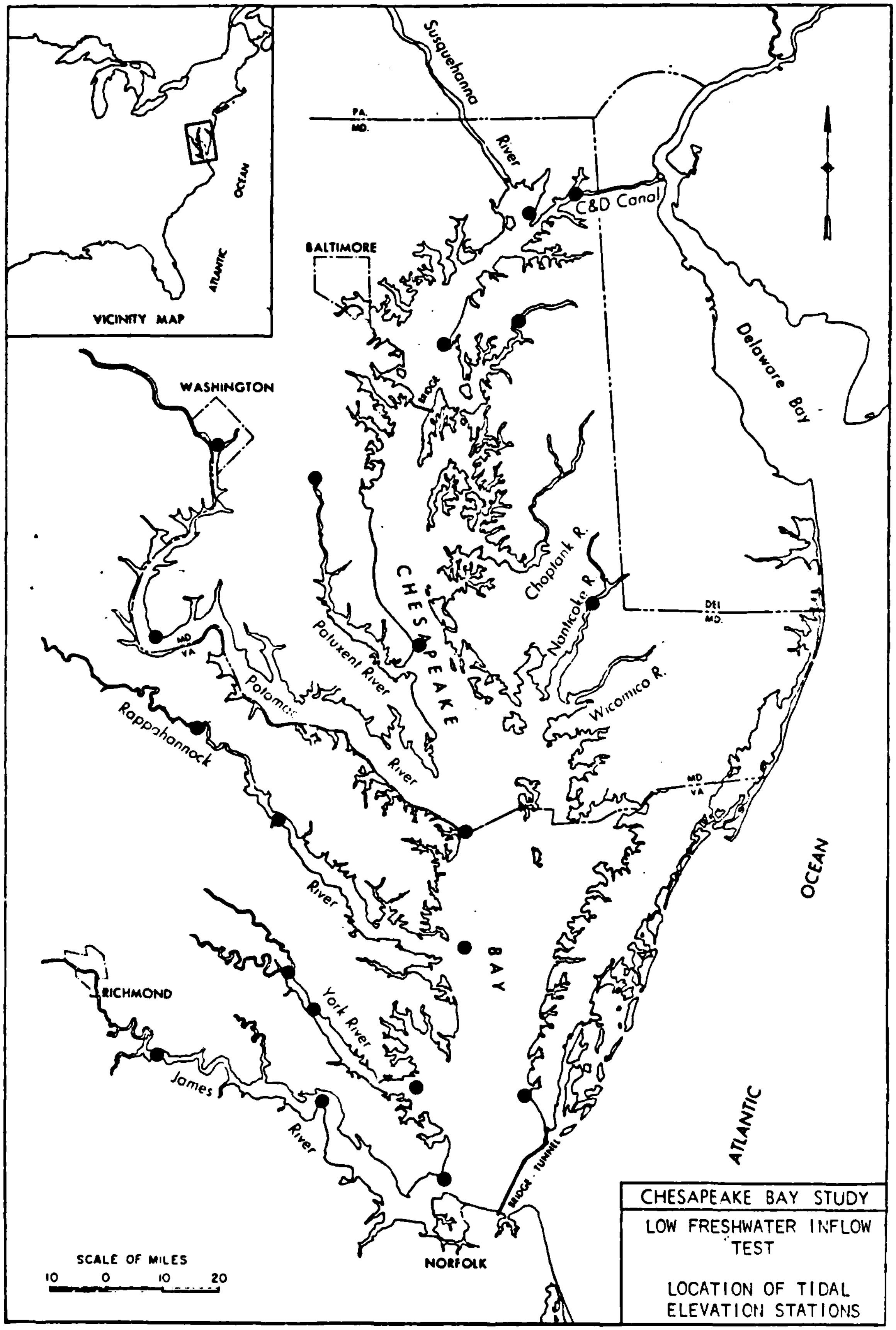


FIGURE D-II-3 LOCATION OF TIDAL ELEVATION STATIONS

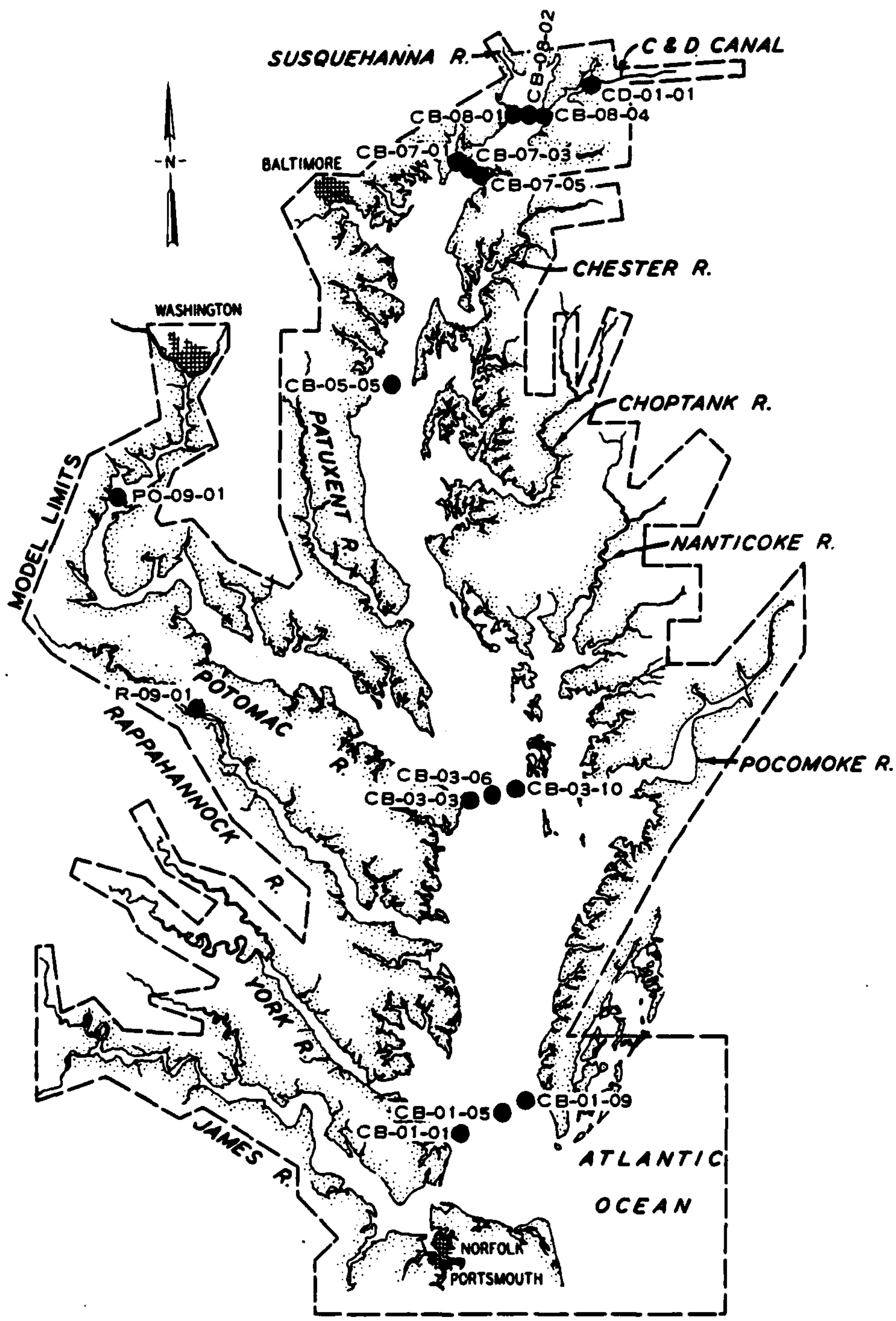


FIGURE D-II-4 LOCATION OF VELOCITY SAMPLING STATIONS

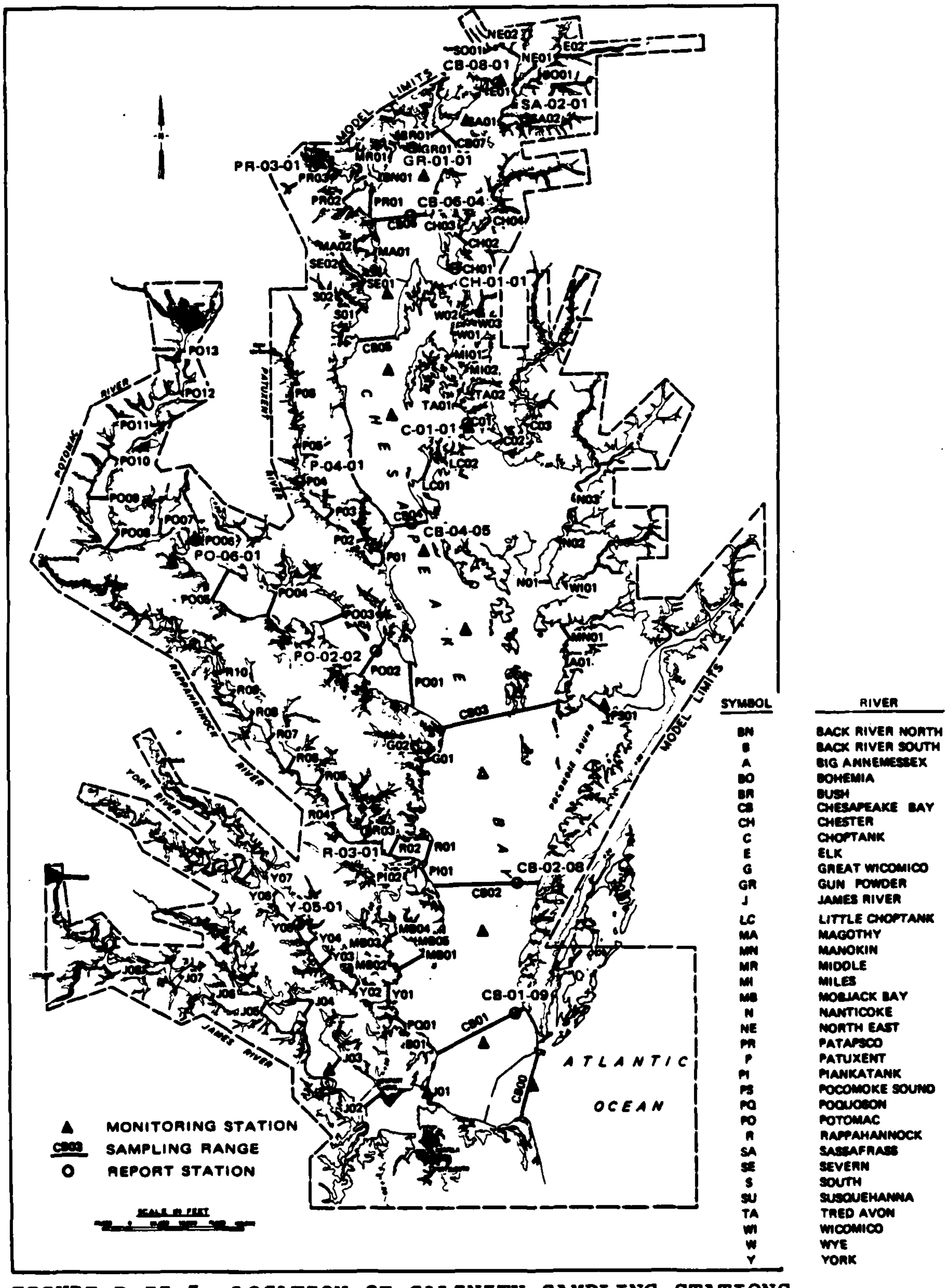


FIGURE D-II-5 LOCATION OF SALINITY SAMPLING STATIONS

only for the influence of the dams, but were also reduced by an amount equal to the incremental increase in consumptive losses between 1965 and 2020. Also at this time, the wastewater treatment plant discharges were increased from their 1960's flow levels to projected year 2020 levels. The average yearly hydrograph following the drought was repeated only three times due to a loss of tide control on the model.

TABLE D-II-1

Salinity Stations

Station	Model Depth (Proto Ft)	Sampling Depths (Proto Ft)
Big Annemessex River		
A-01-01	19	4, 17
A-02-01	7	4
Back River, Virginia		
B-01-01	16	2, 15
Back River, Maryland		
BN-01-01	7	4
BN-02-01	6	3
Bohemia River		
BO-01-01	9	4
Bush River		
BR-01-01	12	10
Choptank River		
C-00-01	18	2, 16
C-00-02	54	2, 27, 52
C-01-01	70	4, 12, 22, 42, 62
C-02-01	31	4, 12, 27
C-03-01	14	4, 11
C-04-01	29	2, 15, 27
Chesapeake Bay		
CB-00-01	59	4, 12, 22, 32
CB-00-02	68	4, 22, 32, 52, 68
CB-00-03	42	4, 22, 32
CB-00-05	20	4, 12, 17
CB-00-07	21	4, 12, 18
CB-00-08	49	4, 22, 42
CB-00-09	17	3, 7, 14
CB-01-01	16	4, 16
CB-01-03	27	4, 14, 27
CB-01-05	52	4, 22, 50
CB-01-07	28	4, 12, 27
CB-01-09	77	4, 22, 42, 62, 72
CB-02-02	26	4, 12, 25
CB-02-04	36	4, 22, 32
CB-02-06	42	4, 22, 42
CB-02-08	59	4, 32, 57
CB-02-10	28	4, 12, 27

TABLE D-II-1 (Continued)

Salinity Stations

Station	Model Depth (Proto Ft)	Sampling Depths (Proto Ft)
Chesapeake Bay (continued)		
CB-03-01	38	4, 22, 38
CB-03-03	68	4, 22, 32, 52, 68
CB-03-04	71	4, 22, 32, 52, 62
CB-03-06	42	4, 22, 37
CB-03-08	27	4, 12, 18
CB-03-10	61	4, 12, 32, 42, 57
CB-03-11	21	4, 15
CB-04-01	36	4, 22, 32
CB-04-03	65	4, 12, 32, 52, 62
CB-04-04	103	4, 22, 52, 72, 92
CB-04-05	102	4, 22, 52, 72, 97
CB-04-06	26	4, 12, 22
CB-04-07	18	4, 16
CB-05-02	37	4, 22, 32
CB-05-04	65	4, 12, 32, 52, 62
CB-05-05	109	4, 32, 52, 82, 109
CB-05-06	25	4, 12, 20
CB-06-01A	55	2, 28, 53
CB-06-01	22	2, 20
CB-06-03	33	2, 12, 32
CB-06-04	37	2, 22, 37
CB-06-05	20	2, 19
CB-07-01	15	5, 10
CB-07-03	34	2, 12, 29
CB-07-04	24	2, 12, 22
CB-07-05	46	2, 22, 38
CB-08-01	21	4, 11, 20
CB-08-02	6	3
CB-08-03	9	5
CB-08-04	16	4, 15
Chesapeake & Delaware Canal		
CD-01-01	39	4, 20, 38

TABLE D-II-1 (Continued)

Salinity Stations

Station	Model Depth (Proto Ft)	Sampling Depths (Proto Ft)
Chester River		
CH-00-01	22	2, 11, 20
CH-00-02	28	2, 14, 26
CH-01-01	55	4, 32, 52
CH-02-01	25	4, 12, 24
CH-02-02	30	4, 14, 26
CH-03-01	18	4, 11
CH-04-01	49	4, 22, 44
CH-05-01	11	2, 9
Elk River		
E-01-01	20	4, 12, 18
E-02-01	10	4, 8
Eastern Bay		
EB-01-01	58	2, 29, 56
EB-01-02	27	2, 14, 25
Fishing Bay		
FB-01-01	21	2, 11, 19
Great Wicomico River		
G-01-01	19	4, 14, 17
Gunpowder River		
GR-01-01	22	2, 12, 22
Hooper Island		
H-01-01	10	2, 8
James River		
J-01-01	16	1, 13
J-01-02	52	1, 23, 43
J-01-03	81	1, 13, 23, 43, 72
J-02-01	14	1, 13
J-02-02	26	1, 13, 23
J-02-03	50	1, 23, 43
J-03-01	20	1, 13, 20
J-03-02	21	1, 13, 20
J-04-01	19	1, 19

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TABLE D-II-1 (Continued)

Salinity Stations

Station	Model Depth (Proto Ft)	Sampling Depths (Proto Ft)
James River (Continued)		
J-04-02	20	1, 13, 20
J-05-01	23	0, 13, 20
J-05-02	41	0, 20, 39
J-06-01	25	3, 13, 23
J-07-01	30	3, 13, 28
J-08-01	30	5, 15, 25
J-09-01	31	2, 16, 29
J-10-01	26	2, 13, 24
Little Choptank River		
LC-01-01	17	4, 12
LC-02-01	22	4, 12, 21
Magothy River		
MA-01-01	21	4, 12, 18
MA-02-01	18	4, 15
Mobjack Bay		
MB-01-01	16	0, 13
MB-01-02	20	0, 20
MB-01-03	20	0, 20
MB-03-01	25	0, 13, 20
MB -04-01	24	13
Miles River		
MI-01-01	38	4, 22, 32
MI-02-01	12	4, 12
Manokin River		
MN-01-01	9	4
MN-02-01	9	5
Middle River		
MR-01-01	9	2
Nanticoke River		
N-01-01	27	4, 12, 24
N-02-01	14	4, 12
N-03-01	14	4, 12
North East River		
NE-01-01	13	4, 11
NE-02-01	9	4

TABLE D-II-1 (Continued)

Salinity Stations

Station	Model Depth (Proto Ft)	Sampling Depths (Proto Ft)
Patuxent River		
P-01-01	44	4, 22, 40
P-01-02	56	4, 32, 52
P-02-01	27	4, 12, 22
P-02-02	80	4, 22, 42, 52, 62
P-03-01	28	4, 12, 22
P-04-01	38	4, 22, 32
P-05-01	13	4, 12
P-06-01	27	4, 12, 22
Potomac River		
PO-01-01	28	2, 12, 22
PO-01-02	40	2, 22, 37
PO-01-03	42	2, 22, 40
PO-01-04	54	2, 32, 50
PO-01-05	32	2, 12, 31
PO-02-01	34	2, 22, 30
PO-02-02	60	2, 12, 32, 42, 60
PO-02-03	34	4, 22, 30
PO-03-01	62	2, 12, 32, 42, 57
PO-03-02	39	2, 22, 36
PO-04-01	30	2, 12, 22
PO-04-02	42	2, 22, 42
PO-05-01	16	2, 12
PO-05-02	20	2, 19
PO-05-03	26	2, 10, 19
PO-06-01	64	2, 12, 22, 42, 62
PO-07-01	20	2, 12
PO-07-02	24	2, 12, 21
PO-08-01	11	1, 6
PO-08-02	20	4, 18
PO-09-01	13	2, 13
PO-09-02	24	2, 11, 21
PO-10-01	30	2, 12, 28
PO-10-02	30	2, 12, 22
PO-11-01	33	2, 12, 32
PO-12-02	61	2, 12, 32, 42, 52
PO-13-02	26	2, 12, 25
PO-14-02	22	4, 12, 22
PO-15-01	47	4, 24, 47
PO-16-01	9	4

TABLE D-II-1 (Continued)

Salinity Stations

Station	Model Depth (Proto Ft)	Sampling Depths (Proto Ft)
Piankatank River		
PI-01-01	23	4, 12, 20
Poquoson River		
PQ-01-01	16	3, 10
Patapsco River		
PR-01-01	16	2, 14
PR-01-02	17	2, 14
PR-01-03	54	2, 32, 53
PR-02-01	17	2, 14
PR-02-02	53	2, 22, 52
PR-03-01	53	2, 22, 52
PR-03-02	23	3, 12, 22
Pocomoke Sound		
PS-01-01	8	4
PS-02-01	14	2, 12
Rappahannock River		
R-01-01	30	1, 13, 30
R-01-02	36	1, 20, 23
R-03-01	60	1, 13, 26, 46, 59
R-03-02	24	1, 13, 20
R-05-01	27	1, 13, 26
R-06-01	19	1, 19
R-07-01	19	1, 18
R-08-01	24	1, 13, 20
R-09-01	16	1, 16
R-10-01	26	1, 16, 26
R-11-01	47	2, 24, 45
R-12-01	42	2, 21, 40
R-13-01	31	2, 16, 29
South River		
S-01-01	17	4, 12
S-02-01	18	4, 17

TABLE D-II-1 (Continued)

Salinity Stations

Station	Model Depth (Proto Ft)	Sampling Depths (Proto Ft)
Sassafras River		
SA-01-01	15	4, 14
SA-02-01	38	4, 22, 37
Severn River		
SE-01-01	20	4, 18
SE-02-01	29	4, 12, 21
SE-02-02	24	2, 12, 22
Susquehanna River		
SU-01-01	16	0, 13
SU-01-02	28	11, 19, 26
Tred Avon River		
TA-01-01	26	4, 12, 23
TA-02-01	20	4, 14, 19
Tangier Sound		
TS-01-01	2	2
TS-01-02	41	2, 21, 39
TS-01-03	5	3
Wye River		
W-01-01	57	4, 32, 51
W-02-01	23	4, 12, 21
W-03-01	15	4, 12
Wicomico River		
WI-01-01	13	4, 11
York River		
Y-01-01	37	3, 23, 33
Y-01-02	56	5, 25, 54
Y-02-01	72	4, 14, 34, 54, 69
Y-03-01	18	9
Y-03-02	30	3, 13, 30
Y-04-01	17	3, 11
Y-04-02	37	12, 18, 25
Y-05-01	30	4, 14, 26
Y-06-01	28	4, 14, 24
Y-07-01	18	4, 17
Y-07-02	15	4, 14

CHAPTER III

TEST RESULTS AND FINDINGS

WATER SURFACE ELEVATION

Water surface elevation data were collected to determine if the reduction in freshwater inflow would indeed affect water surface elevations in the model. There were minute differences between base and future inflow conditions, but they were considered insignificant.

CURRENT VELOCITY

Test personnel attempted to measure current speed and direction at the selected sixteen stations. Due primarily to instrument problems, little data was recovered during this experiment. The data that were recovered, however, suggests that there is little if any change in velocities associated with decreases in freshwater inflow of the magnitude addressed in this study.

SALINITY

Over 500,000 discrete salinity samples were collected during the course of the Low Freshwater Inflow Test. Because of the large size of the salinity data "package," it is not practical to reproduce it in this report. Rather, it is being kept on file by the Corps of Engineers. It is summarized in a report published by the Waterways Experiment Station entitled "Technical Report HL-82-3, The Low Freshwater Inflow Study, Chesapeake Bay Hydraulic Model Investigation, January 1982."

One of the major objectives of the Low Freshwater Inflow Study was to develop a methodology whereby salinity data from the hydraulic model could be used to predict the ecological consequences of depressed freshwater inflow to Chesapeake Bay and its tributary estuarine waters. Personnel from the U.S. Fish and Wildlife Service, the Chesapeake Bay Study Steering Committee, Western Ecosystems Technology, Inc. and the Corps of Engineers worked to this end in a joint effort.

Following the initial review of the model data and establishing the goals for this work it was decided to apply the concept of the "90 day biological season" to the ecological aspects of this study. The "90 day biological season" is known to correspond closely with descrete units of organism life stages. These 90 day biological seasons differ somewhat from calendar seasons and are shown below.

BIOLOGICAL SEASONS

Winter - 1 December to 28 February
Spring - 1 March to 31 May
Summer - 1 June to 31 August
Fall - 1 September to 30 November

These "seasons" were used as the basic time period for all biological analyses. In order to do this, it was necessary to compute average salinities that corresponds with these seasons. The data display and analyses presented in the remainder of this appendix reflects these "biological seasonal" average salinities.

Further review of the seasonal average salinity data was done in order to determine which four consecutive seasons of the historical drought yielded the highest values and largest increases in salinity. These seasons were found to be as follows:

HISTORIC DROUGHT

Summer - June 1965 to Aug 1965
Fall - Sep 1965 to Nov 1965
Winter - Dec 1965 to Feb 1966
Spring - Mar 1966 to May 1966

In turn, the salinity data resulting from the long term average inflow hydrograph was reviewed and edited to determine which seasonal periods would be representative of long term average salinity. Those selected are as follows:

LONG TERM AVERAGE

Spring - Mar to May, 2nd Year
Summer - Jun to Aug, 2nd Year
Fall - Sept to Nov, 3d Year
Winter - Dec to Feb, 3d Year

Seasonal average salinity data were used to develop a series of isohaline maps of the entire estuarine area for the surface, 10 foot and 20 foot depths. (See Plates D-23 through D-76) Separate sets of maps were made for the base test and futures test, and for each season during drought periods and average inflow periods.

To show how the salinity varies over the water column vertically and longitudinally, the salinities are presented along longitudinal profiles. These profiles are developed for Chesapeake Bay, and the major western shore tributaries including the Patuxent, Potomac, York, Rappahannock and James Rivers (See Plates D-71 through D-94). Figure D-III-1 shows the location of the profiles. Both base and future test data are plotted on the same profiles to better illustrate the changes in salinity caused by the consumptive losses. Seasonal average salinities for the station's located along the profiles are tabulated in Attachment D-1.

Reviewing the salinity data presented on the isohaline maps and longitudinal profiles reinforces the fact that the salinity values at each sampling station varied as a function of

- Freshwater inflow
- The amplitude of the tide, and
- The distances from freshwater inflow points or sources of salinity (The ocean boundary).

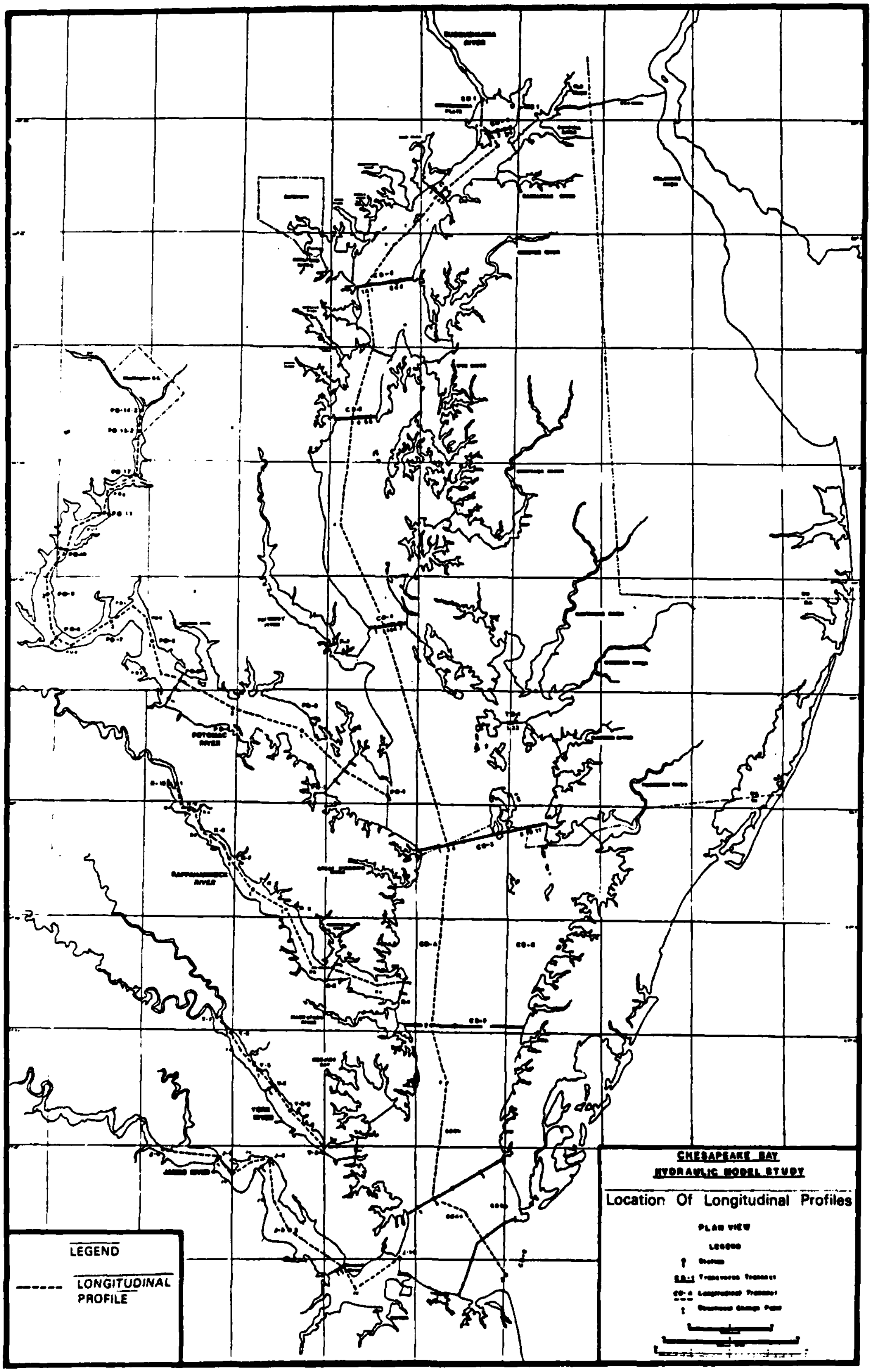

FIGURE D-III-1 LOCATION OF LONGITUDINAL SALINITY PROFILES

For instance

- Increased volumes of freshwater inflow into the system reduce salinity, while decreases in freshwater inflow result in higher salinity.

- The tides continually supply energy for mixing fresh and salt water. During periods of spring tide, with an increase of tidal energy, the estuarine water column is more homogenious (more mixed) than during periods of neap tide.

- Salinity values at stations in the lower Bay are higher than in the upper Bay, reflecting the nearby ocean boundary. In turn, salinities at the head of the Bay are low, reflecting the proximity to discharges of freshwater from the tributary rivers.

As regards to overall salinity change in relation to the difference in the amount of freshwater inflow between base and future tests.

- The Future Drought period is the most saline. The Base Average period is the least saline.

- Spring is the least saline season under all inflow conditions.

- Fall is the most saline season under all inflow conditions.

- The maximum changes in salinity over a given distance occur at the head of the Bay and the mouth of the Bay.

Of primary interest during the Low Freshwater Inflow Study is the movement of isohalines, and consequent increase in salinity that results from reductions in freshwater inflow due to consumptive losses and/or droughts. Figure D-III-2, developed from the isohaline maps included in this Appendix, is a map of Chesapeake Bay showing the location of the 5.0, 15.0, and 25.0 ppt summer seasonal average isohalines. Four individual positions in the Bay are shown for each of the above isohalines; each position corresponding to the particular freshwater inflow hydrograph imposed on the model during the test. Each isohaline is suitably labeled in order to identify the hydrograph with which it is associated (Future Drought, Base Average, etc.). This figure is illustrative of the magnitude of isohaline movement to be expected in the upper, middle, and lower portions of the Bay as a result of consumptive losses and drought.

Figure D-III-2 also shows:

- The difference in location of the various isohalines between the Base Average and Future Average inflow hydrographs, reflecting the reduction in flow caused by consumptive losses during Average Inflow conditions.

- Similarly, the intrusion of the isohalines further up the Bay between Base and Future Drought reflects the effect of consumptive losses on the salinity regime during drought inflow conditions.

- The translation of the 5.0 and 25.0 ppt summer seasonal isohalines, at the head and mouth of the Bay respectively, is less than that of 15.0 ppt in the middle portion of the Bay.

Similar types of analysis of isohaline movement and salinity change due to the effects of consumptive losses for other seasons of the year show the same patterns of movement as during the summer season. Isohalines in the middle portion of the Bay are translated greater distances upstream than those in the upper and lower Bay.

The movement of isohalines in the estuarine system during this test, and changes in absolute salinity have significant impact on the change in the area of habitat for many of the Bay's inhabitants. The significance of changes in salinity and habitat area is discussed in detail in other sections of this report. Shown below, however, are selected data for Chesapeake Bay providing insight into the movement of isohalines and salinity change during this test.

Base Drought vs. Future Drought

Because of the reduction in freshwater inflow due to consumptive losses during periods of drought, salt intruded further upstream during the Future Drought period than during Base Drought.

During the model test, individual isohalines moved as much as 15 miles further upstream at both surface and depth in the upper Bay during the summer season, the period of maximum translation of isohalines. Summer seasonal average salinity in the upper Bay increased as much as 3.8 ppt over base drought salinity as a result of consumptive losses.

The greatest amount of movement of salinity occurred in the middle portion of the Bay where isohalines were translated as much as 50 miles at surface and depth. Summer seasonal average salinity increased as much as 2.6 ppt in the middle Bay.

In the lower Bay, the maximum distance of isohaline movement was 25 and 30 miles respectively at surface and depth. Summer seasonal average salinity increased as much as 2.6 ppt.

The maximum movement of isohalines in the Potomac River was somewhat less than in Chesapeake Bay. Maximum isohaline movement beyond Base Drought conditions was 10 miles at both surface and depth in the upper Potomac, while in the lower Potomac, maximum isohaline movement at surface and depth was 30 miles. Summer seasonal average salinity increased as much as 2.6 ppt and 4.0 ppt, respectively, in the upper and lower Potomac.

In the upper James River, the maximum translation of isohalines between Base and Future Drought at both surface and depth is 14 miles. In the lower portion of the estuary, maximum isohaline movement at the surface was 8 miles, while at depth, it was 12 miles. Summer seasonal average salinity increased as much as 2.4 ppt and 1.6 ppt, respectively, in the upper and lower portions of the James estuary.

Base Average vs. Future Drought

The greatest difference in freshwater inflow during the model test, and consequently, the greatest increases in salinity intrusion is between the Base Average and Future Drought inflow conditions. The difference in seasonal average salinity between these inflow conditions is a function of natural low inflows further compounded by reductions in inflow due to consumptive losses.

During the Future Drought portion of the test, isohalines were translated as far as 35 miles further upstream in the upper Bay at both surface and depth than during the Base Average test. Summer seasonal average salinity increased by as much as 6.5 ppt.

In the middle portion of the Bay, isohalines were translated as much as 80 miles at surface and depth and summer seasonal average salinity increased as much as 4.9 ppt over that of the Base Average period.

Isohalines in the lower Bay were moved as much as 60 miles on the surface and 70 miles at depth beyond their location during Base Average inflow conditions. In turn, summer seasonal salinity increased as much as 4.7 ppt.

In the upper half of the Potomac, isohalines, both surface and at depth, were translated a maximum of 40 miles beyond their Base Average position, while in the lower portion, maximum movement was 60 miles at surface and depth. Summer seasonal average salinity increased as much as 5.8 and 6.0 ppt, respectively, in the upper and lower reaches of the river.

In the James River, isohalines moved a maximum of 41 miles at surface and depth in the upper half of the estuary, and a maximum of 22 miles in the lower half of the estuary. Summer seasonal average salinity increased as much as 7.0 and 6.0 ppt in the upper and lower halves of the estuary, respectively.

Base Average vs. Base Drought

Base Average freshwater inflows simulate the long term average inflows into the system while Base Drought freshwater inflows simulate inflow conditions during the 1960's drought period. The increases in seasonal average salinity between the two inflow conditions are caused by decreased inflow due to the drought period.

During the Base Drought portion of the test, individual isohalines moved as much as 25 miles further upstream in the upper Bay on the surface and at depth than during the Base Average period. Summer seasonal average salinity increased as much as 3.8 ppt.

Isohalines in the middle portion of the Bay were translated as much as 70 miles on the surface and at depth beyond their location during Base Average inflow conditions. Summer seasonal average salinity increased as much as 3.5 ppt.

In the lower Bay, isohalines moved as much as 55 miles on the surface and at depth further upstream than during Base Average. Summer seasonal average salinity increased by as much as 2.8 ppt.

In the upper half of the Potomac River, the maximum movement of isohalines beyond Base Average location was 32 miles, while in the lower portion of the river, isohalines were translated as much as 55 miles. Seasonal summer average salinity increased as much as 4.3 ppt in both the upper and lower portions of the river.

In the James River, individual isohalines moved as much as 27 miles and 15 miles in the upper and lower portions of the river, respectively. Summer seasonal average salinity increased as much as 1.7 ppt in the upper portion of the river and 5.1 ppt in the lower James.

Base Average vs. Future Average

Increases in salinity between Base Average and Future Average model test inflow hydrographic conditions represent the effects on the salinity regime of consumptive losses.

During the future average test, isohalines were translated as much as 15 miles further upstream at both surface and depth in the upper Bay than during the Base Average test. Summer seasonal average salinity in the upper Bay increased as much as 2.8 ppt.

In the middle portion of Chesapeake Bay, individual surface isohalines moved as much as 30 miles beyond Base Average locations, while those at depth moved as much as 50 miles. Seasonal average salinity increased as much as 2.7 ppt in the middle Bay.

In the lower Bay, isohalines moved as much as 40 miles at both surface and depth, increasing summer seasonal average salinity values as much as 2.0 ppt.

In the upper portion of the Potomac, maximum movement of isohalines beyond that of Base Average salinity conditions was 7 miles at the surface and 9 miles at depth. Summer seasonal average salinity increased as much as 1.0 ppt. In the lower Potomac, individual isohalines intruded as much as 20 miles at surface and depth for an increase of 1.5 ppt in summer seasonal salinity.

The maximum translation of isohalines in the upper James River between Base Average and Base Drought periods was 4 miles at the surface and 3 miles at depth. Summer seasonal average salinity increased as much as 7.0 ppt. In the lower James, maximum intrusion beyond Base Average was 22 miles at surface and depth, with a consequent increase in summer seasonal average salinity of up to 1.1 ppt.

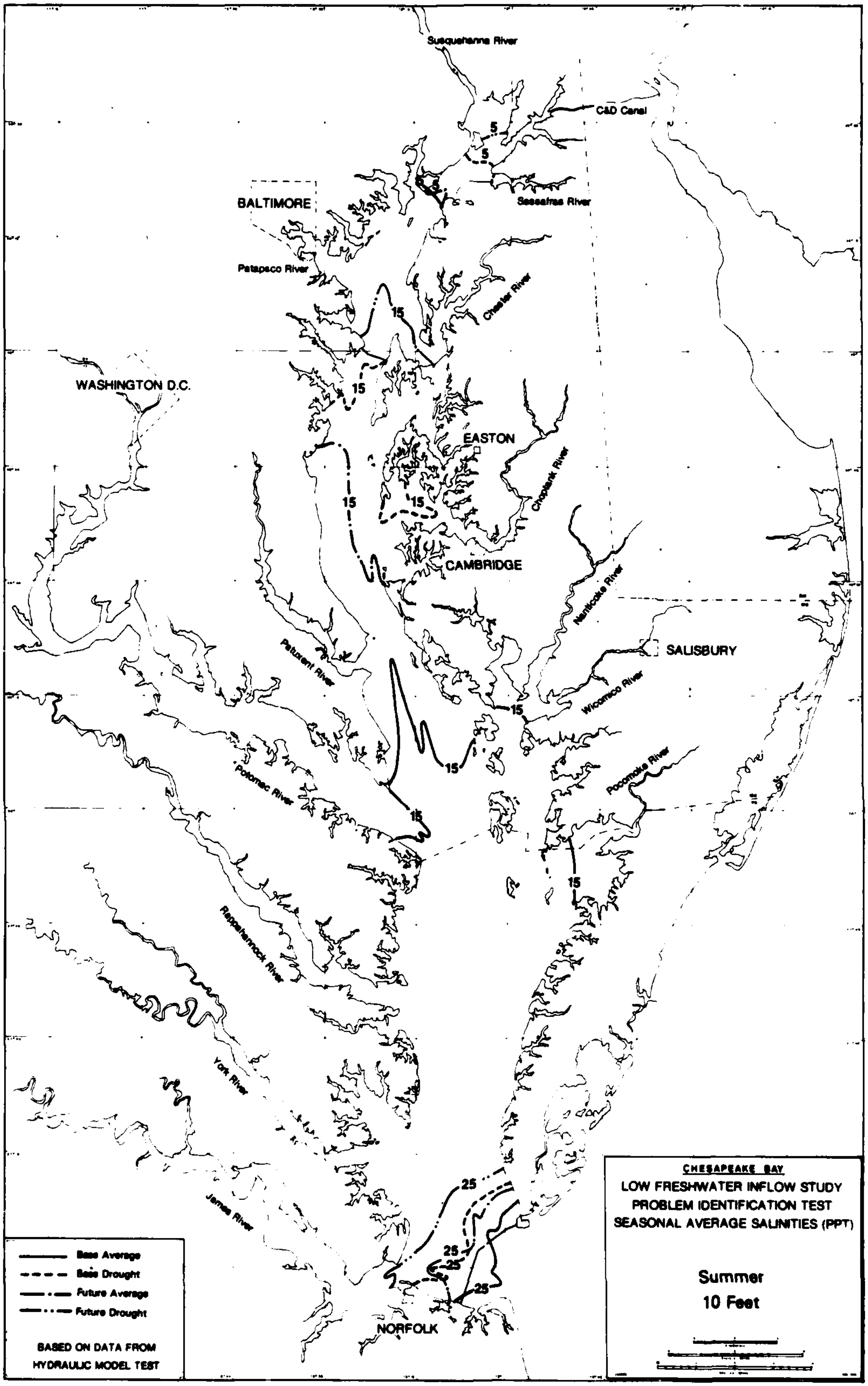

FIGURE D-III-2 TRANSITION OF SELECTED ISOHALINES DURING SUMMER PERIODS

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ATTACHMENT D-1

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

STATION/ DEPTH	SEASON	LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
		SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
CB-00-02													
4'	Summer	22.2	23.6	19.4	19.5	22.0	16.3	24.9	26.4	23.3	25.9	30.6	22.4
	Fall	24.6	26.6	22.7	26.2	29.9	22.9	27.1	28.6	23.9	29.0	31.2	26.4
	Winter	24.0	27.3	22.1	25.2	30.1	23.7	28.4	30.3	25.8	29.5	31.0	26.9
	Spring	20.8	24.4	18.5	21.8	23.5	19.7	24.0	25.6	22.1	25.4	28.5	23.2
22'	Summer	31.4	32.6	30.3	28.1	28.5	27.5	30.8	32.0	29.8	32.6	33.2	31.9
	Fall	30.6	31.9	29.4	31.9	32.6	31.4	31.2	32.4	29.9	31.7	32.2	30.8
	Winter	30.4	31.4	29.6	31.6	32.7	28.4	31.6	32.8	29.6	31.8	32.2	31.4
	Spring	31.5	32.6	29.5	31.9	32.6	31.1	30.7	31.8	29.5	31.9	32.4	31.5
68'	Summer	33.1	33.4	32.8	28.3	28.5	28.1	32.4	32.8	31.8	32.9	33.5	32.5
	Fall	32.5	32.7	32.1	32.4	32.6	32.2	32.4	33.2	30.7	32.2	32.9	31.5
	Winter	32.3	32.8	30.6	32.8	33.4	32.4	32.9	33.8	32.2	31.9	32.5	29.7
	Spring	32.7	33.1	32.2	32.5	32.6	32.4	32.4	32.6	32.2	32.6	33.0	32.3
CB-01-03													
4'	Summer	19.2	21.7	16.3	19.7	22.3	17.6	22.1	24.8	19.6	23.5	25.9	21.6
	Fall	22.0	23.8	19.9	23.6	25.6	21.7	24.6	25.4	23.0	25.7	26.5	24.1
	Winter	21.4	23.2	19.6	23.1	25.5	20.7	25.4	26.1	24.8	26.7	27.8	25.8
	Spring	18.0	21.5	16.1	19.3	22.4	18.0	22.4	24.5	21.2	23.4	26.3	22.3
14'	Summer	20.9	22.8	18.9	21.6	23.7	19.9	23.5	25.5	21.4	24.8	26.7	23.2
	Fall	23.3	24.7	21.7	24.8	26.1	23.2	25.4	26.1	23.5	26.7	27.4	25.0
	Winter	22.7	23.9	21.6	24.5	26.6	22.6	25.9	26.4	25.2	27.2	28.0	25.8
	Spring	19.8	22.3	18.3	21.1	23.6	20.0	23.6	25.1	22.6	24.9	26.5	24.1
27'	Summer	25.6	27.1	23.7	27.6	29.8	25.3	26.8	28.3	25.4	28.0	29.5	26.6
	Fall	25.7	27.0	24.5	27.4	29.4	26.3	27.1	28.4	26.5	27.8	29.1	27.0
	Winter	25.2	26.0	24.4	27.4	29.1	25.8	27.2	28.3	25.5	27.9	29.3	27.1
	Spring	24.5	27.1	22.0	27.3	30.1	25.0	26.5	28.0	25.3	27.5	29.8	26.3

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
CB-02-02													
4'	Summer	16.6	18.4	15.5	17.2	19.5	15.6	19.5	21.2	18.1	20.8	23.2	18.2
	Fall	19.9	21.0	18.1	21.3	22.9	19.2	22.1	23.1	20.2	24.1	24.9	22.2
	Winter	19.2	20.6	17.9	21.0	22.2	20.2	23.2	23.9	22.4	24.9	25.4	24.1
	Spring	15.3	18.7	13.4	16.8	19.8	15.6	19.4	22.9	16.4	21.3	24.7	19.7
12'	Summer	17.7	19.2	16.2	18.0	18.8	15.3	20.5	21.7	19.1	21.8	23.5	19.8
	Fall	21.1	22.1	19.8	22.4	24.0	21.0	22.8	23.6	20.6	24.9	25.5	23.5
	Winter	20.6	21.3	20.0	22.3	23.2	21.3	23.7	24.1	23.4	25.6	26.2	25.1
	Spring	17.2	20.1	15.7	18.4	21.1	16.9	20.6	23.4	19.5	22.3	25.1	21.3
25'	Summer	20.0	21.4	19.0	21.2	23.5	19.6	22.6	23.8	20.7	24.1	25.4	22.2
	Fall	22.7	23.8	21.0	24.2	25.2	22.9	24.1	25.0	23.0	25.9	26.5	25.0
	Winter	22.4	22.9	21.6	23.7	25.0	23.0	24.3	25.0	23.4	26.9	27.7	26.5
	Spring	18.4	21.4	17.1	20.4	23.1	19.7	22.1	23.0	20.7	23.9	25.0	22.6
CB-03-03													
4'	Summer	14.7	16.8	13.4	15.0	17.7	12.8	17.5	19.8	15.9	19.4	21.0	17.4
	Fall	18.6	19.6	17.3	19.8	20.8	18.4	20.7	21.2	19.4	22.0	22.6	20.5
	Winter	17.8	18.8	16.6	17.7	20.7	9.9	21.2	21.9	19.9	22.9	24.0	22.4
	Spring	12.8	16.1	10.7	14.3	17.4	11.8	17.5	20.0	16.5	18.6	21.7	16.2
22'	Summer	17.3	19.7	15.9	17.9	20.7	14.5	20.2	21.5	18.8	21.7	22.7	20.4
	Fall	20.4	21.4	18.7	21.8	22.4	21.0	22.4	23.2	21.7	23.3	24.0	22.4
	Winter	19.9	20.6	19.3	21.6	22.9	16.9	22.5	23.1	21.3	24.4	24.9	23.7
	Spring	16.1	19.2	14.2	17.8	21.1	16.2	20.1	22.0	18.5	21.4	24.1	19.9
68'	Summer	26.0	26.7	24.4	27.5	29.0	25.0	25.8	26.8	25.2	28.4	29.1	27.8
	Fall	26.2	26.9	25.5	27.0	28.0	26.4	25.8	26.8	24.9	27.4	27.8	26.8
	Winter	24.7	25.9	20.7	26.6	27.5	21.3	25.4	26.6	24.8	27.6	27.9	26.4
	Spring	24.7	26.1	22.8	25.5	28.8	17.8	24.5	25.7	23.7	27.2	28.0	26.4

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
CB-4-03													
4'	Summer	14.2	16.0	12.5	15.3	17.4	13.6	16.4	18.1	14.3	18.3	20.3	15.6
	Fall	17.4	18.0	16.5	18.7	19.9	17.6	19.3	20.3	18.1	21.3	22.0	20.1
	Winter	16.0	17.0	14.7	15.8	17.7	14.6	19.3	20.2	16.9	21.4	23.1	19.9
	Spring	11.7	14.5	10.1	12.5	15.6	10.9	14.9	16.8	13.8	16.2	18.9	15.2
32'	Summer	17.3	18.5	16.1	18.1	19.2	16.5	18.6	19.9	17.3	20.5	21.8	19.0
	Fall	19.3	19.7	18.5	20.9	21.3	20.1	21.0	21.7	20.1	22.7	23.3	21.9
	Winter	19.0	19.6	18.4	19.9	20.8	19.6	21.3	21.9	20.9	23.4	23.7	23.0
	Spring	16.1	17.8	15.0	18.8	20.1	18.4	19.1	20.9	18.1	20.9	22.5	19.5
62'	Summer	21.6	22.0	21.2	22.3	23.3	17.0	21.7	21.9	21.5	23.8	24.2	23.3
	Fall	21.7	22.3	21.0	23.5	24.3	22.7	22.5	22.8	22.2	24.0	24.4	23.4
	Winter	21.7	22.3	21.0	22.5	23.6	21.9	22.9	23.4	22.3	24.7	25.8	21.8
	Spring	20.0	21.0	19.2	22.0	23.8	21.1	22.3	22.8	21.1	23.8	24.4	23.1
CB-05-02													
4'	Summer	10.7	13.5	8.1	11.7	14.7	9.6	14.2	16.4	10.9	14.8	16.3	13.6
	Fall	14.4	16.2	13.4	15.6	16.9	14.2	17.6	18.4	15.4	19.4	20.3	17.7
	Winter	11.7	14.0	10.2	13.0	14.4	11.6	16.1	17.8	10.2	17.5	19.5	13.1
	Spring	6.9	9.3	5.1	6.8	8.7	5.0	9.7	12.9	6.6	10.6	12.6	8.4
22'	Summer	14.1	16.1	13.3	16.8	18.2	15.3	16.8	17.9	15.5	18.9	20.1	17.3
	Fall	17.5	18.0	16.7	19.2	19.5	18.1	19.1	19.6	18.3	21.3	21.9	20.5
	Winter	16.7	17.3	15.8	18.5	19.0	17.8	19.4	19.6	18.7	21.7	22.1	20.6
	Spring	13.1	15.7	11.8	13.9	15.3	13.2	16.4	18.3	15.5	18.3	20.5	17.7
32'	Summer	15.9	16.7	15.0	17.8	18.9	17.2	17.4	18.2	15.7	19.7	20.6	18.7
	Fall	18.2	18.7	17.6	19.7	20.0	19.1	19.4	20.0	18.6	21.3	21.8	20.8
	Winter	17.9	18.6	17.1	19.7	20.2	19.3	20.0	20.2	19.6	22.1	22.7	20.7
	Spring	15.2	16.9	14.1	16.7	17.6	16.1	18.0	19.5	16.8	20.2	21.2	20.3

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
CB-06-01A													
2'	Summer	4.9	7.7	3.2	4.6	7.7	2.1	8.3	11.2	4.4	9.8	15.2	4.4
	Fall	8.8	11.1	5.6	9.2	11.8	5.5	13.1	15.0	11.0	14.7	15.9	12.3
	Winter	4.6	6.0	3.0	3.3	5.0	2.3	9.1	12.3	1.7	12.9	14.0	0.2
	Spring	1.6	3.4	0.6	1.6	3.1	1.1	2.8	5.9	1.1	2.4	4.1	0.9
28'	Summer	13.1	14.7	12.2	15.5	16.9	14.8	14.7	15.8	13.7	17.5	18.8	16.6
	Fall	15.5	16.3	14.7	17.6	18.2	16.7	17.2	18.0	15.4	19.1	19.7	18.5
	Winter	15.4	16.7	14.2	17.6	18.5	17.0	17.9	19.0	17.0	19.5	20.1	19.2
	Spring	12.6	14.8	10.0	15.5	18.1	14.8	16.3	18.6	14.0	18.8	21.2	16.7
53'	Summer	16.1	16.9	15.6	18.9	19.4	17.9	17.2	18.1	16.6	20.2	20.7	19.9
	Fall	18.0	18.6	17.3	20.4	20.9	20.0	19.4	20.1	18.8	20.9	21.8	20.5
	Winter	18.0	18.7	17.3	20.3	20.8	19.8	20.1	20.6	19.8	22.1	22.5	21.4
	Spring	16.3	17.6	15.1	18.5	20.5	17.6	18.9	20.3	17.3	20.9	22.0	20.5
CB-07-03													
2'	Summer	3.3	5.9	1.3	3.6	6.5	1.6	6.7	10.4	1.7	9.8	12.6	5.6
	Fall	5.8	7.9	2.9	6.6	9.7	2.7	9.8	12.3	6.4	11.2	14.1	8.4
	Winter	2.2	3.7	1.2	2.2	4.3	1.2	6.1	10.3	1.1	6.8	10.8	1.4
	Spring	0.5	1.1	0.1	0.3	1.2	0.0	1.5	4.8	0.3	1.4	1.7	0.4
12'	Summer	5.6	8.1	3.0	6.5	9.5	4.3	9.4	11.2	6.3	12.1	14.2	8.2
	Fall	9.0	10.3	7.0	10.1	12.0	7.6	12.3	13.4	10.2	14.1	14.8	13.1
	Winter	5.4	6.4	3.8	6.9	8.2	5.0	9.4	11.9	2.5	13.1	14.1	4.4
	Spring	1.2	2.5	0.3	0.9	3.0	0.0	3.2	6.5	0.5	4.2	6.6	1.8
29'	Summer	10.0	11.9	7.8	10.4	13.2	8.5	11.2	12.5	9.6	14.1	15.4	12.2
	Fall	12.4	13.6	10.7	13.2	13.7	11.7	14.3	15.3	12.0	15.7	16.8	14.1
	Winter	11.9	13.4	9.7	13.8	16.4	11.5	13.9	15.7	11.6	16.1	17.7	14.9
	Spring	8.0	13.1	3.7	7.0	13.5	2.2	12.2	16.2	8.1	12.2	19.0	13.0

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

STATION/ DEPTH	SEASON	LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
		SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
CB-08-01													
4'	Summer	0.1	0.3	0.1	0.1	0.5	0.0	1.1	2.3	0.0	3.8	6.5	0.0
	Fall	0.4	1.0	0.1	0.7	1.8	0.0	3.5	5.0	2.1	3.8	7.5	1.6
	Winter	0.3	0.3	0.3	0.15	0.2	0.0	0.7	2.0	0.1	1.0	3.3	0.0
	Spring	0.1	0.3	0.0	0.1	0.2	0.0	0.1	0.1	0.1	0.05	0.1	0.0
11'	Summer	0.1	0.3	0.0	0.1	0.5	0.0	1.7	3.7	0.0	4.6	6.9	0.2
	Fall	0.5	1.3	0.1	0.9	2.0	0.0	2.4	5.1	1.1	5.3	7.6	3.3
	Winter	0.3	0.3	0.2	0.2	0.2	0.1	0.8	2.5	0.1	1.4	4.1	0.0
	Spring	0.1	0.3	0.0	0.1	0.2	0.1	0.1	0.2	0.1	0.0	0.1	0.0
20'	Summer	0.1	0.4	0.0	0.1	0.6	0.0	1.8	4.0	0.0	5.1	6.9	0.3
	Fall	0.5	1.4	0.1	1.3	3.0	0.0	4.2	5.4	2.5	6.6	8.3	4.7
	Winter	0.3	0.3	0.2	0.2	0.2	0.1	1.0	3.2	0.1	2.8	6.3	0.1
	Spring	0.1	0.3	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
SU-01-01													
1'	Summer	0.2	0.3	0.2	0.1	0.8	0.0	0.1	0.4	0.0	0.05	0.1	0.0
	Fall	0.2	0.4	0.1	0.2	0.4	0.1	0.1	0.1	0.0	0.2	0.7	0.0
	Winter	0.4	0.9	0.0	0.2	0.7	0.1	0.2	0.6	0.0	0.1	0.2	0.0
	Spring	0.1	0.2	0.0	0.1	0.9	0.0	0.2	0.7	0.0	0.0	0.0	0.0
13'	Summer	0.3	0.3	0.3	0.0	0.0	0.0	0.1	0.1	0.0	1.2	2.9	0.1
	Fall	0.1	0.2	0.1	0.2	0.2	0.1	0.4	0.8	0.0	1.8	3.8	0.4
	Winter	0.0	0.0	0.0	0.2	0.4	0.2	0.1	0.1	0.0	0.1	0.2	0.0
	Spring	0.05	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

STATION/ DEPTH	SEASON	LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
		SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
P-01-1													
4'	Summer	14.0	16.3	12.3	14.7	16.1	12.9	16.3	17.9	13.8	18.0	20.2	15.8
	Fall	17.0	17.6	16.0	17.9	18.8	16.7	18.9	20.3	18.1	21.2	21.8	20.3
	Winter	15.6	16.8	14.3	17.0	18.0	16.1	19.2	19.7	17.6	21.7	22.9	18.5
	Spring	11.5	14.1	10.0	12.7	14.5	11.2	14.8	17.1	13.0	16.2	18.3	14.9
22'	Summer	15.9	17.3	14.9	17.2	18.5	15.8	17.5	18.9	16.4	19.4	20.7	18.0
	Fall	18.4	18.9	17.4	18.9	19.4	18.2	20.2	20.9	19.2	21.9	22.5	21.0
	Winter	18.3	18.9	17.6	19.7	20.1	19.0	20.6	21.2	19.9	22.4	22.8	20.2
	Spring	15.2	17.3	13.4	16.6	17.8	15.6	18.0	19.9	16.3	20.0	22.1	18.0
40'	Summer	16.6	18.1	15.2	17.7	18.9	16.9	18.1	19.3	17.2	20.2	21.3	19.1
	Fall	18.7	19.3	17.8	19.3	19.9	18.6	20.4	21.2	19.4	22.2	23.0	21.6
	Winter	18.6	19.3	18.0	20.1	20.4	19.5	21.0	21.6	20.6	22.4	23.0	21.1
	Spring	16.3	18.0	14.9	18.0	18.9	16.9	19.3	20.6	17.9	21.4	22.5	19.9
P-02-02													
4'	Summer	8.6	9.6	6.2	7.5	10.6	6.3	12.9	15.7	9.7	12.6	15.2	9.7
	Fall	13.5	13.9	9.6	13.2	15.1	11.1	17.0	17.9	16.1	16.8	18.2	15.0
	Winter	9.7	11.9	8.2	9.8	12.6	7.0	18.1	19.1	16.3	19.5	22.7	17.6
	Spring	4.7	7.7	3.2	6.1	7.5	5.4	10.3	11.4	9.1	10.0	12.4	8.3
22'	Summer	15.4	17.0	14.0	16.3	18.1	15.0	17.6	19.2	16.2	19.5	22.4	17.7
	Fall	18.2	18.8	16.9	19.2	20.6	13.8	20.2	20.5	19.3	21.4	22.2	20.4
	Winter	18.0	18.7	17.3	19.4	20.9	18.8	20.8	21.1	20.1	22.5	22.7	21.6
	Spring	14.5	16.7	13.0	16.9	18.6	15.5	18.0	20.4	16.7	19.5	22.0	18.3
62'	Summer	16.0	17.4	14.8	17.3	19.1	16.2	18.1	19.5	17.2	20.0	22.4	19.1
	Fall	18.4	18.8	17.6	19.9	20.5	19.1	20.3	20.9	19.5	21.7	22.7	20.7
	Winter	18.5	18.9	17.8	20.0	20.4	19.5	21.0	21.5	20.7	22.5	22.7	22.3
	Spring	16.3	17.6	15.0	19.0	19.9	18.1	19.8	20.5	18.4	21.2	22.3	20.0

AD-A161 481 CHESAPEAKE BAY LOW FRESHWATER INFLOW STUDY APPENDIX B 4/5
PLAN FORMULATION AP..(U) CORPS OF ENGINEERS BALTIMORE
MD BALTIMORE DISTRICT SEP 84 CHB-84-L-APP-B-C-D

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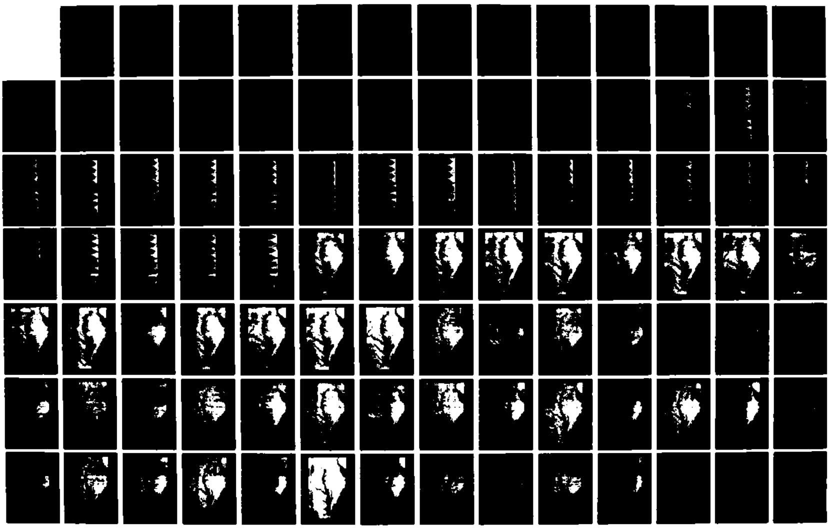

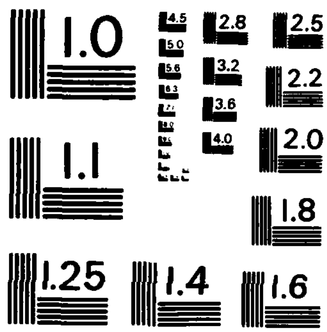

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
P-03-01													
4'	Summer	-	-	-	9.4	13.4	6.3	13.1	15.5	9.5	15.2	17.3	11.6
	Fall	14.9	15.7	13.3	14.6	15.6	13.5	17.2	18.6	15.0	18.6	20.5	16.6
	Winter	11.1	13.7	8.5	9.9	11.6	8.5	17.2	19.1	9.4	19.4	22.5	14.6
	Spring	5.6	7.6	3.8	5.1	6.0	3.6	8.7	9.6	6.6	11.0	12.4	9.2
12'	Summer	-	-	-	16.2	18.2	14.4	17.0	18.3	15.5	18.7	20.2	17.2
	Fall	18.0	18.6	16.8	19.1	20.1	18.3	20.0	21.4	18.2	21.1	22.1	20.0
	Winter	17.9	18.4	17.2	19.0	19.6	18.1	20.9	21.7	19.8	22.2	22.6	21.7
	Spring	13.7	16.4	12.2	14.3	16.0	13.1	16.6	18.7	15.3	18.6	21.4	17.7
22'	Summer	-	-	-	17.2	18.3	16.2	17.4	18.8	16.3	19.2	20.4	18.3
	Fall	18.2	18.7	17.5	19.5	20.2	18.7	20.2	21.4	19.1	21.5	22.3	20.5
	Winter	18.5	18.8	17.9	19.9	20.2	19.5	21.0	21.6	20.3	22.1	22.5	22.0
	Spring	15.8	17.6	14.6	16.5	18.5	15.1	18.2	20.1	17.3	20.4	22.3	18.8
P-04-01													
4'	Summer	8.2	11.2	5.7	9.5	14.1	6.7	12.8	15.4	10.8	13.3	15.5	10.2
	Fall	11.3	11.6	10.1	13.0	15.2	10.5	16.3	17.2	15.2	17.1	18.6	15.1
	Winter	9.6	11.5	7.8	11.3	12.7	8.8	16.8	19.6	10.7	17.3	11.5	19.0
	Spring	5.7	7.8	4.0	7.4	10.4	5.7	10.0	11.8	7.9	11.3	13.5	9.6
22	Summer	14.8	16.1	13.8	16.3	17.9	15.0	17.1	18.3	16.2	18.4	19.5	17.2
	Fall	17.0	17.9	15.0	19.0	19.9	18.0	19.7	20.2	19.9	20.8	21.9	19.7
	Winter	17.7	18.2	17.1	19.2	19.5	18.8	20.3	20.7	19.4	22.0	22.1	21.7
	Spring	14.8	16.6	13.4	16.5	18.1	14.7	17.9	20.1	16.3	19.5	21.4	18.1
32	Summer	14.9	16.2	14.0	16.7	18.3	15.2	17.3	18.5	16.5	18.6	19.7	17.2
	Fall	17.5	18.1	16.9	19.0	20.0	18.2	19.8	20.4	19.0	20.9	21.9	19.9
	Winter	17.9	18.4	17.1	19.4	19.8	18.8	20.6	20.9	20.2	22.0	22.2	21.7
	Spring	15.4	16.9	13.4	17.1	18.3	15.4	18.3	20.2	16.4	20.1	21.6	18.3

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

STATION/ DEPTH	SEASON	LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
		SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
P-05-01													
4'	Summer	6.5	9.4	4.5	8.4	10.9	6.0	9.9	11.9	7.6	12.8	15.1	10.0
	Fall	10.2	11.6	8.6	11.5	13.7	9.1	13.1	14.2	10.2	16.3	18.0	14.4
	Winter	7.3	9.5	5.4	8.4	11.0	6.2	13.0	15.1	2.9	16.6	18.9	6.9
	Spring	3.1	4.9	1.7	4.0	6.5	2.3	6.2	7.6	4.9	8.8	10.3	7.0
12'	Summer	14.2	15.7	12.9	15.7	17.3	14.4	16.6	17.3	15.8	17.8	19.1	16.5
	Fall	16.9	17.9	15.9	18.[illegible]	19.5	17.4	18.5	20.2	16.7	20.2	21.3	19.1
	Winter	16.9	17.7	16.0	18.7	19.3	18.1	19.1	19.9	18.5	21.4	21.7	20.9
	Spring	14.4	16.7	12.7	15.8	17.8	13.9	16.7	18.6	15.6	19.2	21.0	18.0
P-6-01													
4'	Summer	.8	1.7	0.4	.7	1.2	0.3	4.1	7.0	1.0	4.0	7.7	1.2
	Fall	1.6	2.9	0.4	1.2	3.2	0.1	6.6	9.4	2.7	6.5	10.2	3.2
	Winter	1.0	2.8	0.4	.4	0.8	0.2	7.0	9.9	0.7	7.8	13.0	0.6
	Spring	0.2	0.4	0.0	.4	0.8	0.1	1.1	2.4	0.2	.8	4.7	.4
12'	Summer	2.1	4.1	0.8	2.9	5.8	1.2	7.5	9.3	5.4	8.3	10.6	6.4
	Fall	5.3	7.1	4.1	6.4	8.1	4.4	10.0	12.0	6.6	11.6	13.8	9.8
	Winter	2.2	3.9	0.6	3.1	6.2	1.0	10.5	12.5	0.7	11.5	13.9	1.0
	Spring	0.2	0.5	0.1	.4	0.8	0.1	3.6	5.8	0.8	4.0	6.4	.6
22'	Summer	2.6	4.4	1.5	3.4	6.2	1.9	7.8	10.0	5.5	8.5	10.8	6.5
	Fall	5.8	7.4	4.4	6.9	8.5	4.9	10.9	12.5	9.0	11.9	14.1	9.9
	Winter	2.8	4.7	1.2	3.8	6.7	2.2	11.6	13.1	6.8	12.4	14.1	7.1
	Spring	0.2	0.9	0.1	.5	1.5	0.2	4.5	6.6	2.5	5.5	7.5	3.6

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
PO-01-4													
2'	Summer	11.6	14.3	9.7	11.6	13.9	9.8	15.9	17.8	13.6	16.3	17.9	14.1
	Fall	15.6	17.2	13.1	16.0	17.3	14.3	19.0	19.9	16.4	21.8	22.5	21.2
	Winter	13.9	17.8	11.1	--	--	--	20.3	21.2	18.8	22.3	25.5	21.5
	Spring	8.6	13.9	6.6	8.8	10.1	7.6	14.0	17.8	10.5	15.8	19.7	13.0
32'	Summer	17.3	18.5	16.2	18.7	20.0	17.7	19.4	21.0	17.9	20.4	20.8	19.7
	Fall	19.6	20.3	18.8	20.0	21.8	18.1	21.5	22.0	20.5	23.4	23.5	23.3
	Winter	19.6	20.2	19.1	--	--	--	22.2	22.4	22.0	23.9	23.9	23.9
	Spring	16.5	19.2	15.4	17.8	18.9	15.1	19.6	22.1	18.4	21.1	23.4	19.9
50'	Summer	19.9	21.3	18.7	21.1	22.9	20.3	21.8	23.0	20.5	23.0	24.1	21.9
	Fall	21.9	22.7	21.2	22.2	23.7	20.5	23.3	23.7	22.5	25.0	25.5	24.5
	Winter	22.0	22.4	20.7	--	--	--	24.1	24.5	23.6	25.3	25.9	23.1
	Spring	19.3	22.8	17.3	20.8	21.9	19.7	22.2	23.9	20.7	23.8	25.2	22.3
PO-02-02													
2'	Summer	11.1	12.9	9.2	11.5	13.2	9.9	15.1	17.1	12.5	14.6	17.4	11.3
	Fall	15.5	16.9	13.4	16.3	18.0	14.6	18.5	19.3	16.9	19.5	21.0	17.7
	Winter	12.7	16.3	11.1	--	--	--	19.7	20.2	18.4	21.2	22.1	19.1
	Spring	7.8	10.9	6.4	8.5	10.2	7.1	12.7	15.2	10.4	12.4	15.2	8.7
32'	Summer	16.8	18.0	15.7	18.3	19.7	17.1	19.1	20.0	17.7	20.1	21.3	18.4
	Fall	19.6	20.2	18.6	20.7	21.4	19.6	21.1	21.5	20.3	22.6	23.3	21.7
	Winter	19.0	19.9	18.9	--	--	--	21.6	21.8	21.4	23.4	23.8	23.3
	Spring	15.7	18.1	14.2	17.5	18.8	16.5	19.2	21.3	18.3	20.5	23.0	19.4
60'	Summer	20.3	21.0	19.8	21.8	22.7	21.1	22.0	22.8	18.9	22.9	23.6	21.8
	Fall	22.1	22.6	21.4	23.2	23.7	22.6	23.3	23.6	22.8	24.4	25.2	23.5
	Winter	22.0	22.5	21.5	--	--	--	23.9	24.2	23.6	25.3	25.6	24.2
	Spring	19.8	21.1	18.5	21.5	22.8	20.7	22.7	23.7	22.1	23.9	25.0	22.6

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
PO-03-01													
2'	Summer	9.6	11.8	8.1	10.8	11.7	7.7	13.0	14.9	10.8	9.3	9.9	8.7
	Fall	13.7	14.5	12.2	14.6	15.8	13.4	16.9	17.7	15.1	19.2	21.1	17.4
	Winter	11.4	13.6	10.1	--	--	--	18.9	20.3	16.3	21.5	24.5	16.8
	Spring	6.5	9.2	5.0	6.0	9.3	4.7	11.5	14.1	8.3	12.5	14.9	8.9
32'	Summer	17.4	18.8	16.4	18.4	20.0	7.7	18.7	19.6	17.5	20.3	21.2	18.8
	Fall	19.5	20.2	19.1	20.6	21.2	20.1	20.2	20.8	19.0	22.5	23.2	21.4
	Winter	19.6	20.3	19.1	--	--	--	21.8	22.0	21.4	23.3	23.6	23.1
	Spring	16.8	18.3	15.5	18.1	19.3	17.4	19.6	21.4	18.4	21.0	23.1	19.7
57'	Summer	18.5	19.4	17.6	19.8	21.3	18.2	20.5	21.3	19.6	21.8	22.5	20.9
	Fall	20.6	21.4	20.0	21.5	22.1	21.0	21.7	22.2	21.0	22.9	24.2	22.8
	Winter	21.0	21.7	20.8	--	--	--	23.0	23.5	22.4	23.3	24.4	17.9
	Spring	18.2	20.3	16.1	19.6	21.1	18.6	21.5	22.8	20.4	22.9	24.1	21.4
PO-04-02													
2'	Summer	7.3	9.7	5.3	8.6	10.6	6.6	11.1	13.5	8.6	11.2	14.7	8.9
	Fall	11.4	12.7	9.6	11.4	12.2	10.3	15.6	16.6	13.4	16.7	22.6	14.7
	Winter	7.6	10.0	5.6	--	--	--	16.5	18.4	10.7	20.3	22.6	18.8
	Spring	3.8	6.9	2.6	4.6	6.4	3.9	8.4	11.5	4.8	6.6	11.5	3.8
22'	Summer	14.4	16.0	13.4	15.7	17.9	14.4	16.7	17.5	15.7	18.3	19.7	16.8
	Fall	17.5	18.3	16.6	17.6	18.2	16.8	18.8	20.1	17.8	21.0	21.8	20.1
	Winter	17.1	17.9	15.9	--	--	--	20.3	20.7	19.6	22.2	22.4	21.9
	Spring	13.9	16.1	12.0	15.0	16.4	14.0	17.6	19.6	16.2	19.1	20.3	17.1
42'	Summer	16.4	17.9	15.4	17.5	18.9	16.9	18.0	19.2	16.8	19.8	20.9	18.2
	Fall	18.7	19.3	17.9	19.1	19.4	18.7	20.0	20.5	19.2	22.0	22.7	20.8
	Winter	19.2	19.7	18.7	--	--	--	21.0	21.5	20.6	22.6	23.1	19.3
	Spring	16.7	18.5	15.1	18.0	18.9	16.8	19.4	21.2	18.1	20.9	23.2	19.5

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

STATION/ DEPTH	SEASON	LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
		SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
PO-05-03													
2'	Summer	7.5	9.3	5.9	7.1	9.9	6.1	11.0	13.4	7.8	12.9	15.5	10.2
	Fall	11.2	12.4	9.6	12.5	13.2	11.3	15.2	15.8	13.3	17.3	18.5	15.5
	Winter	8.6	11.3	5.8	--	--	--	15.9	17.8	8.8	18.8	19.8	12.5
	Spring	4.5	7.2	3.5	5.7	5.9	4.4	8.2	11.4	4.8	10.2	12.9	6.6
10'	Summer	9.4	11.4	8.0	9.5	11.7	8.3	12.6	14.2	10.3	14.6	16.5	12.5
	Fall	13.3	13.9	12.1	14.2	15.0	13.3	16.6	17.1	15.4	18.5	19.6	16.4
	Winter	11.7	13.1	10.1	--	--	--	17.7	19.0	14.7	19.8	20.8	16.9
	Spring	7.0	10.0	6.1	7.6	8.2	6.8	11.7	14.5	8.9	13.0	16.1	10.3
19'	Summer	11.1	13.2	9.1	12.0	16.2	9.8	14.1	16.4	11.1	17.3	19.0	14.8
	Fall	15.0	15.9	13.5	16.4	17.3	15.3	18.0	18.6	16.6	20.1	21.3	18.3
	Winter	13.4	15.4	12.0	11.9	--	--	19.0	19.9	17.0	21.4	21.8	20.4
	Spring	8.2	11.9	7.0	9.2	10.7	7.8	13.7	16.3	10.9	16.5	19.5	13.7
PO-06-01													
2'	Summer	7.7	10.4	4.9	--	--	--	11.5	14.1	7.4	13.1	15.8	8.7
	Fall	11.4	13.3	9.3	12.7	13.5	10.5	15.8	16.4	14.2	17.6	18.6	15.9
	Winter	7.8	11.2	4.2	--	--	--	16.1	17.9	7.6	19.2	20.8	9.1
	Spring	4.0	5.7	2.4	4.6	6.8	2.4	8.2	11.1	3.8	9.6	12.5	3.9
22'	Summer	10.1	12.0	8.2	10.7	13.0	9.1	13.0	14.9	10.9	14.6	16.5	12.6
	Fall	13.3	14.2	12.1	14.6	15.2	13.3	16.5	16.9	15.2	18.4	19.3	16.8
	Winter	12.0	13.8	10.9	--	--	--	17.2	18.1	15.2	19.7	20.4	17.6
	Spring	7.6	10.4	6.6	7.8	8.8	7.4	12.1	14.6	9.9	13.5	16.6	11.2
62'	Summer	13.0	14.9	11.2	14.3	15.5	12.6	14.9	15.8	13.6	16.9	18.4	15.3
	Fall	15.3	16.6	14.5	16.8	18.5	15.6	17.3	18.1	16.3	19.3	20.6	18.0
	Winter	15.9	17.2	14.7	--	--	--	18.4	19.3	17.1	20.5	21.1	19.8
	Spring	12.6	15.5	10.4	13.9	15.3	12.4	15.4	18.5	13.4	17.8	21.2	15.9

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

STATION/ DEPTH	SEASON	LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
		SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
PO-07-02													
2'	Summer	5.6	7.4	4.1	6.9	9.0	5.1	8.8	11.8	4.5	11.4	13.6	8.0
	Fall	9.1	10.7	7.4	11.0	12.2	8.7	13.0	14.3	11.0	15.9	16.6	13.8
	Winter	5.8	8.4	3.8	8.3	10.6	7.0	14.6	15.9	5.8	18.2	19.8	9.6
	Spring	2.8	4.5	1.4	3.2	6.0	1.7	5.6	8.1	3.1	9.5	10.8	5.1
12'	Summer	9.1	11.8	6.9	10.3	13.4	8.0	12.0	13.3	9.9	14.1	16.2	11.9
	Fall	12.4	13.5	10.7	14.1	15.2	12.7	15.1	17.1	12.3	17.4	19.1	15.5
	Winter	11.8	13.6	10.1	13.1	14.7	12.3	16.7	17.8	13.4	18.9	19.7	16.7
	Spring	6.5	10.4	4.3	7.5	9.6	6.5	11.1	14.8	7.8	13.3	17.0	12.4
21'	Summer	10.2	12.1	8.7	11.3	14.5	9.7	12.9	14.2	12.1	14.7	16.4	13.0
	Fall	13.3	14.4	12.4	14.4	15.3	13.6	15.7	17.5	13.6	17.6	19.1	16.2
	Winter	13.3	14.8	11.7	14.4	15.6	13.7	17.2	18.0	15.8	18.9	19.6	17.8
	Spring	8.7	11.8	7.1	9.5	12.7	8.0	12.8	15.3	11.2	14.9	17.4	13.1
PO-08-02													
4'	Summer	4.2	6.9	1.9	4.8	7.9	1.7	8.2	11.0	2.8	9.6	12.8	4.5
	Fall	7.4	9.0	4.5	9.1	11.0	8.2	12.1	13.6	9.3	14.0	15.3	10.8
	Winter	3.7	7.6	1.5	5.2	9.5	2.7	13.2	14.8	4.0	16.0	17.1	3.9
	Spring	1.1	2.7	0.2	1.2	2.9	0.0	5.5	8.1	1.2	6.5	9.2	1.9
18'	Summer	5.9	8.4	4.0	6.9	10.1	4.6	10.0	11.7	8.0	11.4	13.4	9.4
	Fall	9.5	10.4	8.3	10.8	11.8	9.6	13.4	14.8	11.7	15.0	16.4	13.6
	Winter	7.7	10.1	5.2	8.9	11.6	6.9	14.4	15.6	9.7	16.9	17.2	13.9
	Spring	2.4	5.0	0.6	2.5	5.0	1.1	7.5	9.8	4.5	8.4	11.6	5.4

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
PO-09-02													
2'	Summer	1.5	2.6	0.5	1.8	4.4	0.7	4.6	5.7	2.7	6.1	9.1	3.4
	Fall	4.0	5.5	2.6	5.1	6.5	3.7	8.6	9.8	6.4	10.8	11.9	9.0
	Winter	1.3	3.0	0.2	2.3	4.4	0.9	9.6	11.6	2.3	12.3	15.8	2.4
	Spring	0.3	0.4	0.2	0.07	0.3	0.0	1.4	2.7	0.0	2.3	3.5	0.5
11'	Summer	1.8	3.2	0.7	2.4	4.9	0.9	5.8	7.4	3.2	7.8	10.4	4.6
	Fall	4.9	6.1	3.6	6.4	7.8	5.1	9.4	10.6	7.5	11.7	13.0	10.3
	Winter	2.0	4.2	0.3	3.8	6.6	2.0	10.9	12.2	3.8	14.0	15.1	6.1
	Spring	0.3	0.3	0.2	0.08	0.5	0.0	2.0	3.8	0.0	4.0	5.5	0.6
21'	Summer	3.1	5.7	1.0	4.0	7.9	1.4	7.4	9.1	4.3	9.0	11.7	4.8
	Fall	6.8	8.0	5.5	8.1	9.3	6.8	11.2	13.1	9.0	12.6	14.5	11.3
	Winter	3.6	7.5	0.7	6.6	10.9	3.3	12.2	13.8	6.1	13.9	15.6	8.5
	Spring	0.3	0.5	0.3	0.2	1.0	0.0	3.9	8.3	0.3	4.9	7.4	0.9
PO-10-02													
2'	Summer	0.7	1.5	0.2	1.1	2.7	0.2	2.6	3.5	0.8	4.6	7.2	1.2
	Fall	2.8	3.8	1.8	3.8	5.5	2.5	6.7	8.0	3.7	8.9	10.0	7.3
	Winter	0.8	2.1	0.2	0.2	2.6	0.1	7.5	9.4	2.0	10.9	11.6	10.2
	Spring	0.3	0.3	0.1	0.02	0.1	0.0	0.6	1.9	0.0	1.1	2.3	0.5
12'	Summer	0.7	1.9	0.2	0.4	0.7	0.2	4.3	6.4	1.2	6.1	9.0	2.3
	Fall	3.5	4.4	2.4	--	--	--	7.9	9.3	6.8	10.3	11.6	8.8
	Winter	1.0	3.0	0.2	--	--	--	8.5	10.6	2.3	12.2	12.8	11.3
	Spring	0.3	0.3	0.1	0.0	0.0	0.0	0.8	2.5	0.0	2.0	3.3	0.1
22'	Summer	0.8	2.1	0.2	2.6	4.4	0.2	4.6	6.6	1.6	6.8	9.4	3.9
	Fall	4.0	5.3	2.7	6.5	6.7	6.0	8.2	9.4	6.6	10.9	12.5	9.1
	Winter	1.2	3.6	0.2	--	--	--	9.4	11.5	3.6	12.8	13.3	12.0
	Spring	0.3	0.3	0.1	0.05	0.1	0.0	1.0	2.7	0.0	2.0	5.4	0.1

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
PO-11-01													
2'	Summer	0.1	0.2	0.0	0.4	0.8	0.2	1.9	4.1	0.1	3.5	5.9	0.6
	Fall	1.0	1.9	0.6	2.1	3.0	1.5	5.1	6.0	3.8	7.1	8.1	5.4
	Winter	0.1	0.2	0.0	0.2	1.1	0.0	5.8	7.4	0.2	7.8	9.8	1.1
	Spring	0.1	0.1	0.0	0.2	0.0	0.6	0.1	0.4	0.0	0.2	0.9	0.1
12'	Summer	0.1	0.2	0.0	0.4	1.1	0.2	2.2	4.3	0.1	4.1	6.5	0.8
	Fall	1.2	2.2	0.5	2.6	3.5	1.5	5.8	7.1	4.4	8.0	9.2	6.8
	Winter	0.1	0.3	0.0	0.3	1.3	0.0	6.6	8.6	0.3	9.9	11.0	1.1
	Spring	0.1	0.1	0.0	0.03	0.2	0.0	0.1	0.5	0.1	0.3	1.5	0.1
32'	Summer	0.1	0.3	0.1	0.5	2.3	0.2	2.7	4.7	0.1	5.0	7.3	1.9
	Fall	1.7	2.8	0.9	3.5	4.8	2.3	6.3	7.9	4.6	8.7	10.6	7.1
	Winter	0.2	1.3	0.0	0.6	4.6	0.0	7.5	9.4	0.7	10.9	12.0	3.8
	Spring	0.1	0.1	0.0	0.03	0.3	0.0	0.2	1.0	0.0	0.4	2.6	0.0
PO-12-02													
2'	Summer	0.0	0.1	0.0	0.2	0.2	0.1	0.6	1.6	0.1	1.7	3.7	0.2
	Fall	0.1	0.3	0.0	0.4	0.9	0.0	2.8	3.7	1.1	4.8	5.9	3.1
	Winter	0.3	0.3	0.2	0.1	0.1	0.0	3.4	5.0	0.1	5.5	7.6	0.1
	Spring	0.1	0.1	0.0	0.2	0.2	0.0	0.1	0.1	0.0	0.1	0.2	0.0
32'	Summer	0.0	0.1	0.0	0.2	0.2	0.1	0.6	1.8	0.0	2.1	4.1	0.0
	Fall	0.1	0.3	0.0	0.3	0.9	0.0	2.8	4.8	2.1	5.7	7.4	4.4
	Winter	0.2	0.3	0.2	0.02	0.2	0.0	3.4	5.5	0.1	6.5	8.5	0.1
	Spring	0.1	0.1	0.0	0.2	0.2	0.0	0.1	0.1	0.1	0.05	0.1	0.0
52'	Summer	0.1	0.1	0.0	0.2	0.2	[illegible]	0.8	1.9	0.0	2.1	4.3	0.0
	Fall	0.1	0.3	0.0	0.3	1.0	0.0	3.3	4.4	1.8	5.7	7.4	4.6
	Winter	0.2	0.3	0.2	0	0.0	0.0	4.5	6.2	0.1	6.6	8.6	0.1
	Spring	0.1	0.1	0.0	0.2	0.2	0.0	0.1	0.2	0.0	0.0	0.0	0.0

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
PO-13-02													
2'	Summer	0.3	0.4	0.2	0.3	0.3	0.2	0.0	0.0	0.0	0.6	1.3	0.1
	Fall	0.0	0.1	0.0	0.2	0.5	0.1	0.5	0.7	0.2	2.0	2.8	0.2
	Winter	0.2	0.3	0.2	0.2	0.5	0.1	1.1	2.0	0.1	2.7	4.8	0.2
	Spring	0.1	0.1	0.0	0.08	0.2	0.0	0.1	0.1	0.0	0.08	0.1	0.0
12'	Summer	0.3	0.3	0.3	0.2	0.2	0.2	0.0	0.0	0.0	0.6	1.8	0.0
	Fall	0.0	0.1	0.0	0.1	0.2	0.1	0.8	1.5	0.2	2.9	4.3	2.0
	Winter	0.2	0.3	0.2	0.1	0.2	0.1	1.8	2.9	0.1	4.2	5.6	0.2
	Spring	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.08	0.1	0.0
25'	Summer	0.3	0.3	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.6	2.1	0.0
	Fall	0.0	0.1	0.0	0.1	0.2	0.1	1.0	2.1	0.2	3.3	4.8	2.0
	Winter	0.2	0.3	0.2	0.0	0.0	0.0	2.1	3.3	0.1	4.4	5.8	0.1
	Spring	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.08	0.1	0.0
PO-14-02													
4'	Summer	0.0	0.0	0.0	0.01	0.1	0.0	0.1	0.1	0.1	0.7	1.5	0.2
	Fall	0.0	0.2	0.0	0.2	0.4	0.1	0.6	0.9	0.4	2.4	3.3	1.3
	Winter	0.3	0.3	0.2	0.1	0.2	0.0	0.9	1.8	0.0	3.4	5.0	0.1
	Spring	0.1	0.5	0.0	0.2	0.5	0.2	0.1	0.1	0.0	0.07	0.1	0.0
12'	Summer	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.1	0.1	0.5	1.2	0.1
	Fall	0.0	0.1	0.0	0.2	0.2	0.2	0.5	0.6	0.3	2.8	4.2	1.8
	Winter	0.2	0.3	0.2	0.1	0.1	0.0	1.4	2.4	0.0	4.0	5.2	0.0
	Spring	0.1	0.1	0.0	0.2	0.4	0.2	0.1	0.1	0.0	0.08	0.1	0.0
22'	Summer	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.6	1.8	0.0
	Fall	0.0	0.0	0.0	0.1	0.2	0.1	0.4	0.6	0.3	3.0	4.6	1.8
	Winter	0.2	0.3	0.2	0.02	0.1	0.0	1.6	2.6	0.0	3.9	5.0	0.0
	Spring	0.0	0.0	0.0	0.2	0.2	0.1	0.1	0.1	0.0	0.07	0.1	0.0

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
R-01-02													
1'	Summer	16.0	18.0	14.6	17.1	19.0	15.4	18.7	20.5	16.9	20.1	21.4	18.4
	Fall	19.0	20.1	17.7	19.7	21.5	17.9	21.2	21.9	19.6	23.0	23.9	21.6
	Winter	18.6	19.8	17.6	--	--	--	22.4	23.0	21.8	24.3	24.9	23.7
	Spring	13.7	17.9	11.9	15.9	19.3	14.6	18.6	19.8	17.2	20.4	23.0	19.4
20'	Summer	17.9	19.5	16.5	18.9	20.7	17.4	20.1	21.7	18.4	21.1	22.2	19.7
	Fall	20.0	20.8	19.1	21.2	22.9	18.8	21.9	22.6	20.3	23.5	24.6	22.6
	Winter	19.8	20.8	18.9	--	--	--	22.7	23.2	21.8	24.7	25.0	24.4
	Spring	16.6	19.7	15.6	17.7	19.2	16.9	20.0	22.7	18.6	21.7	24.4	20.5
33'	Summer	18.1	19.7	16.9	19.3	20.9	17.8	20.3	22.0	18.8	21.6	22.9	20.1
	Fall	20.3	21.1	19.4	21.2	22.9	15.3	22.4	23.0	21.4	23.8	24.7	22.8
	Winter	20.3	21.3	18.9	--	--	--	22.9	23.4	22.0	24.8	25.2	24.6
	Spring	17.3	20.1	16.2	18.3	19.8	17.6	20.3	22.8	18.9	21.9	24.5	20.7
R-03-01													
13'	Summer	15.6	17.3	13.6	16.7	18.4	15.4	17.8	20.0	15.2	19.5	20.9	17.7
	Fall	18.8	19.8	17.8	19.7	20.8	18.2	21.2	21.6	20.2	22.3	23.3	20.5
	Winter	18.5	19.8	17.8	--	--	--	22.2	22.8	21.6	23.8	24.1	23.2
	Spring	14.9	17.6	14.0	15.6	17.0	14.7	19.0	21.2	17.6	20.5	22.6	19.0
26'	Summer	16.3	18.0	15.0	17.3	19.1	16.3	18.7	20.5	16.4	19.2	21.9	18.7
	Fall	19.3	20.2	18.0	20.5	21.5	19.0	21.3	21.7	20.6	23.1	24.1	21.9
	Winter	18.9	20.1	18.3	--	--	--	22.3	23.0	21.8	24.0	24.6	23.8
	Spring	15.6	18.3	14.4	17.3	18.3	15.9	19.5	21.9	18.0	21.0	23.6	10.7
59'	Summer	17.3	18.9	15.9	18.3	20.4	17.0	19.6	21.1	18.0	20.6	22.1	19.3
	Fall	19.8	21.1	18.6	21.1	22.3	19.4	21.8	22.2	20.9	23.2	24.3	22.0
	Winter	19.9	20.5	19.3	--	--	--	22.6	23.3	22.0	24.1	24.7	23.9
	Spring	16.8	19.0	15.5	17.3	19.1	16.6	20.1	22.5	18.5	21.6	24.0	20.1

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
R-05-01													
1'	Summer	8.9	12.2	6.1	--	--	--	13.8	16.4	9.6	13.7	17.7	9.7
	Fall	13.2	15.2	10.7	--	--	--	18.0	18.9	16.0	--	--	--
	Winter	9.5	13.2	6.1	--	--	--	17.8	20.3	7.5	--	--	--
	Spring	4.9	9.1	2.3	--	--	--	10.4	15.2	4.8	14.4	17.7	5.5
13'	Summer	13.3	14.9	11.6	14.1	15.0	13.2	16.8	18.2	15.2	17.8	19.1	16.1
	Fall	16.9	18.1	15.8	17.9	19.5	17.2	19.4	19.7	18.6	20.1	22.1	19.6
	Winter	16.4	17.2	15.8	--	--	--	20.2	20.8	19.5	22.3	22.6	21.1
	Spring	13.2	15.7	11.5	13.6	15.6	12.2	17.6	19.3	16.3	19.0	20.5	16.9
26'	Summer	14.3	15.8	13.2	15.6	18.3	14.0	17.4	19.2	15.9	18.4	19.9	16.7
	Fall	17.5	18.9	16.3	18.7	20.1	18.1	19.7	20.2	19.1	21.2	22.6	20.0
	Winter	17.6	18.9	16.7	--	--	--	20.8	21.2	20.3	22.7	22.8	22.2
	Spring	14.3	17.2	12.5	15.1	17.1	13.5	18.3	20.7	17.0	20.0	22.6	17.9
R-06-01													
1'	Summer	7.6	10.4	4.1	7.3	9.8	4.2	12.7	15.0	8.1	14.0	17.0	9.0
	Fall	11.6	14.3	8.1	12.1	15.0	9.4	16.9	18.0	15.7	18.4	20.5	15.3
	Winter	6.9	10.8	3.2	6.4	10.2	3.3	19.0	20.0	5.2	20.9	21.7	6.1
	Spring	3.6	6.9	1.7	3.8	6.8	1.8	12.4	13.4	4.4	12.7	13.0	4.4
19'	Summer	12.9	14.4	11.1	13.8	16.5	11.7	15.9	17.3	15.0	17.4	18.7	15.4
	Fall	15.9	17.4	14.7	16.0	18.2	13.9	18.5	19.4	16.8	20.1	20.9	18.4
	Winter	15.4	16.7	14.2	17.3	19.0	15.6	20.2	21.0	19.1	21.7	22.1	20.5
	Spring	12.4	15.3	10.2	13.6	16.6	11.5	16.9	19.9	14.7	15.2	20.9	10.9

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

STATION/ DEPTH	SEASON	LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
		SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
R-07-01													
1'	Summer	5.9	7.3	4.3	5.9	7.9	3.8	10.1	11.9	6.9	11.7	14.1	8.0
	Fall	9.4	10.9	7.5	9.7	11.9	7.0	15.2	16.2	9.2	17.0	18.4	14.2
	Winter	5.6	7.9	3.6	5.3	7.8	3.7	17.3	18.1	4.3	17.5	20.0	4.8
	Spring	2.7	4.3	1.5	2.8	4.9	1.4	10.0	10.7	3.5	7.3	11.1	3.8
18'	Summer	11.2	13.9	9.2	12.5	15.3	9.8	14.5	15.5	13.2	16.0	17.4	13.9
	Fall	14.4	16.0	13.4	15.1	16.5	14.2	17.5	18.4	15.0	19.0	20.4	17.8
	Winter	14.2	16.5	11.9	15.9	18.4	12.8	19.2	19.8	16.2	20.9	21.2	18.7
	Spring	10.7	14.3	8.0	11.9	13.9	9.3	14.7	18.7	12.3	17.6	20.2	16.9
R-08-01													
1'	Summer	4.6	6.6	3.6	5.0	7.4	2.8	9.1	11.5	5.8	10.5	13.2	6.0
	Fall	8.3	9.9	6.0	8.8	11.0	6.5	13.7	14.7	9.0	15.8	17.2	12.4
	Winter	4.5	7.0	3.2	4.5	7.8	1.9	15.4	16.8	3.7	18.4	19.0	4.0
	Spring	1.9	3.3	0.8	2.3	4.0	0.9	7.8	9.7	2.5	8.7	10.2	2.9
13'	Summer	7.6	10.6	5.7	8.8	11.8	6.0	12.0	14.0	10.2	13.3	15.1	11.1
	Fall	11.3	12.2	10.0	12.0	13.0	10.6	15.6	16.3	13.0	16.3	16.1	15.7
	Winter	10.0	11.9	7.3	11.8	14.8	9.0	16.8	17.1	11.5	18.4	19.5	14.1
	Spring	8.5	10.1	3.8	7.7	11.7	4.6	11.2	13.7	9.0	12.8	17.5	10.1
20'	Summer	8.1	11.0	6.1	9.4	12.6	6.2	12.4	14.3	10.5	13.4	15.2	11.3
	Fall	11.6	12.8	10.5	12.3	13.9	10.2	15.3	16.4	11.6	17.2	18.5	15.8
	Winter	10.9	12.9	7.7	12.4	15.8	9.2	16.4	17.5	12.3	18.8	19.7	14.6
	Spring	6.9	11.4	3.4	8.4	12.9	4.8	11.9	15.4	9.1	13.8	17.8	10.2

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

STATION/ DEPTH	SEASON	LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
		SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
R-09-01													
1'	Summer	2.6	4.7	0.8	3.0	6.2	1.9	7.8	9.8	5.9	9.1	11.3	7.1
	Fall	5.7	7.1	4.0	6.3	8.6	4.1	12.4	13.7	9.3	13.9	15.4	10.7
	Winter	1.9	3.4	1.2	2.1	4.0	1.1	12.5	15.0	2.5	15.8	17.4	3.4
	Spring	0.5	1.4	0.1	0.8	1.7	0.3	4.2	7.5	1.1	6.4	7.1	1.6
16'	Summer	3.5	6.1	2.1	4.4	7.0	2.8	9.2	11.2	7.0	10.4	13.0	7.7
	Fall	7.2	8.3	6.0	7.9	9.1	6.4	13.3	14.5	11.6	14.9	16.3	13.0
	Winter	3.6	5.7	2.4	4.3	7.2	2.9	14.7	15.2	3.7	15.9	17.7	6.9
	Spring	0.08	2.0	0.2	1.3	2.6	0.4	6.3	8.8	2.0	7.3	14.4	3.1
R-10-01													
1'	Summer	0.65	1.5	0.2	0.9	2.1	0.4	3.9	6.0	1.4	5.0	7.7	1.9
	Fall	2.80	4.1	1.6	2.9	4.4	1.3	8.7	9.8	5.0	11.0	12.5	8.0
	Winter	0.45	1.0	0.2	0.4	0.9	0.1	9.9	11.5	1.4	12.8	14.6	1.5
	Spring	0.05	0.3	0.0	0.7	0.2	0.0	1.6	3.3	0.2	2.2	3.2	0.2
16'	Summer	1.55	3.4	0.1	1.9	4.1	0.5	6.4	8.3	4.0	7.9	10.4	5.0
	Fall	4.9	6.2	3.2	5.4	6.6	3.2	11.4	12.5	7.1	13.4	14.8	11.1
	Winter	1.08	2.5	0.2	1.2	2.4	0.4	11.9	13.6	2.4	15.9	16.2	3.4
	Spring	0.06	0.3	0.0	0.8	0.3	0	3.5	5.9	0.4	4.1	8.1	0.5
26'	Summer	1.8	3.7	0.2	2.2	4.4	0.7	6.5	8.5	4.5	8.2	10.9	5.7
	Fall	5.1	6.4	3.3	5.6	6.7	3.2	11.4	12.5	9.1	13.6	14.9	11.4
	Winter	1.2	2.6	0.3	1.5	3.1	0.4	12.0	13.6	2.6	13.6	16.5	3.9
	Spring	0.05	0.3	0.0	0.08	0.3	0.0	4.3	7.1	0.5	5.6	10.7	0.6

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
R-11-01													
2'	Summer	0.13	0.6	0.0	0.4	1.0	0.2	3.1	5.4	0.8	4.4	7.2	1.4
	Fall	1.7	2.7	0.6	2.0	3.1	0.4	7.7	9.1	4.9	10.0	11.7	7.2
	Winter	0.1	0.2	0.1	0.3	0.7	0.2	9.2	10.4	0.6	10.7	13.3	1.1
	Spring	0.29	0.3	0.1	0.05	0.4	0.0	0.9	2.4	0.2	1.2	3.0	0.0
24'	Summer	0.18	0.7	0.0	0.4	1.4	0.1	3.5	6.0	0.9	4.9	7.7	2.0
	Fall	1.9	3.0	0.0	2.3	3.6	0.5	8.6	10.0	6.9	10.6	12.3	8.3
	Winter	0.1	0.2	0.0	0.2	0.3	0.2	9.7	11.1	0.5	13.2	14.0	1.2
	Spring	0.28	0.3	0.1	0.05	0.1	0.0	1.0	2.8	0.1	1.8	4.0	0.0
45'	Summer	0.20	0.9	0.0	0.4	1.6	0.1	3.9	6.3	1.2	5.3	8.1	2.5
	Fall	2.18	3.3	0.8	2.6	3.8	0.6	8.7	10.3	6.0	11.1	12.5	8.5
	Winter	0.10	0.2	0.0	0.2	0.3	0.1	10.0	11.5	0.5	12.3	14.3	1.6
	Spring	0.28	0.3	0.1	0.0	0.0	0.0	1.5	3.5	0.1	1.9	4.5	0.0
R-12-01													
2'	Summer	0.01	0.1	0.0	0.2	0.8	0.1	0.8	2.0	0.1	1.4	3.3	0.1
	Fall	0.12	0.2	0.1	0.1	0.2	0.0	4.0	5.1	2.3	5.6	7.3	3.4
	Winter	0.25	0.3	0.2	0.0	0.0	0.0	4.0	5.5	0.1	6.3	8.2	0.1
	Spring	0.0	0.1	0.0	0.2	0.3	0.0	0.1	0.2	0.1	0.0	0.0	0.0
21'	Summer	0.0	0.0	0.0	0.10	0.1	0.1	1.0	2.4	0.1	1.6	4.1	0.1
	Fall	0.10	0.2	0.0	0.09	0.3	0.0	4.8	6.2	2.5	6.7	8.8	4.3
	Winter	0.25	0.3	0.2	0.02	0.2	0.0	5.3	6.7	0.3	7.6	9.7	0.1
	Spring	0.0	0.0	0.0	0.12	0.2	0.0	0.1	0.2	0.1	0.05	0.1	0.0
40'	Summer	0.0	0.0	0.0	0.10	0.1	0.1	1.0	2.6	0.1	1.7	4.2	0.1
	Fall	0.1	0.2	0.0	0.08	0.3	0.0	4.8	6.3	2.8	6.8	8.8	4.4
	Winter	0.27	0.3	0.2	0.00	0.0	0.0	5.3	6.8	0.2	8.4	10.0	0.1
	Spring	0.01	0.1	0.0	0.12	0.2	0.0	0.1	0.2	0.1	0.05	0.1	0.0

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
R-13-01													
2'	Summer	0.09	0.1	0.0	0.2	0.9	0.1	0.03	0.1	0.0	0.15	0.8	0.1
	Fall	0.00	0.0	0.0	0.01	0.1	0.0	0.10	0.1	0.0	0.15	0.3	0.0
	Winter	0.19	0.2	0.15	0.06	0.3	0.0	0.11	0.2	0.1	0.23	0.4	0.0
	Spring	0.15	0.3	0.0	0.08	0.1	0.0	0.11	0.2	0.1	0.05	0.1	0.0
16'	Summer	0.10	0.1	0.1	0.1	0.2	0.1	0.04	0.1	0.0	0.05	0.5	0.0
	Fall	0.02	0.1	0.0	0.0	0.0	0.0	0.10	0.1	0.1	0.05	0.2	0.0
	Winter	0.2	0.2	0.2	0.0	0.0	0.0	0.10	0.1	0.1	0.09	0.2	0.0
	Spring	0.09	0.1	0.0	0.09	0.1	0.0	0.10	0.1	0.1	0	0.0	0.0
29'	Summer	0.10	0.1	0.1	0.1	0.1	0.1	0.05	0.1	0.0	0.05	0.2	0.0
	Fall	0.01	0.1	0.0	0.0	0.0	0.0	0.3	0.1	0.1	0.04	0.2	0.0
	Winter	0.21	0.3	0.2	0.0	0.0	0.0	0.3	0.1	0.0	0.09	0.2	0.0
	Spring	0.09	0.1	0.0	0.1	0.2	0.0	0.2	0.1	0.0	0.02	0.1	0.0
Y-01-02													
5'	Summer	18.7	20.4	17.3	18.4	19.7	17.0	21.2	22.9	18.5	22.7	24.0	21.4
	Fall	21.4	22.0	20.2	22.4	23.2	21.3	23.3	23.9	22.2	25.1	25.7	23.8
	Winter	20.2	21.4	19.4	--	--	--	23.0	24.0	20.9	25.9	26.3	24.6
	Spring	17.7	19.1	17.0	16.3	17.9	14.1	20.7	22.2	19.0	23.5	24.1	22.9
25'	Summer	20.0	21.0	18.7	20.0	21.7	19.5	22.2	23.6	20.8	23.4	24.7	22.1
	Fall	22.3	23.0	21.6	24.0	24.7	23.3	23.8	24.2	23.4	25.4	26.2	24.4
	Winter	21.8	22.5	21.2	--	--	--	24.1	24.5	23.4	26.3	26.5	25.6
	Spring	19.7	21.0	18.6	19.6	20.6	17.2	22.1	23.4	21.4	24.8	25.9	23.6
54'	Summer	28.6	30.2	27.4	28.9	30.5	21.7	27.8	30.0	24.0	29.2	31.2	26.4
	Fall	26.9	29.6	23.2	27.6	24.6	23.3	26.6	29.3	24.4	27.1	29.4	25.3
	Winter	27.0	29.2	23.2	--	--	--	24.8	26.6	23.8	26.6	28.3	25.7
	Spring	29.5	31.3	23.8	29.0	30.7	23.6	27.3	30.3	23.5	26.7	28.7	24.1

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
Y-02-01													
4'	Summer	15.9	18.4	13.2	19.0	21.7	16.4	21.2	22.4	20.0	21.9	23.1	20.3
	Fall	20.5	21.4	20.0	21.8	22.3	20.5	23.4	23.5	14.2	23.6	25.3	16.2
	Winter	18.3	20.3	16.2	--	--	--	20.9	23.9	13.2	24.5	25.8	18.8
	Spring	16.0	18.7	13.5	17.4	18.2	16.7	19.8	21.7	16.9	20.6	22.2	18.6
34'	Summer	20.7	21.9	18.8	21.3	22.6	19.5	22.5	24.0	16.7	23.5	24.1	22.4
	Fall	22.3	22.9	22.1	23.4	23.9	23.0	21.4	24.0	16.4	24.9	25.5	24.0
	Winter	21.7	22.5	20.7	--	--	--	20.1	24.2	15.0	25.8	26.2	25.1
	Spring	20.3	21.0	18.8	20.5	21.7	19.3	22.2	23.0	21.4	24.2	25.2	23.0
69'	Summer	28.5	29.9	26.7	28.2	30.6	23.3	27.5	29.8	21.3	27.8	30.3	24.0
	Fall	26.1	29.3	22.5	25.9	29.9	23.6	24.7	28.8	21.2	25.6	28.6	24.3
	Winter	25.9	28.7	22.1	--	--	--	21.9	24.6	16.3	25.9	26.4	25.3
	Spring	28.7	30.8	21.7	28.6	30.4	21.6	26.2	30.3	23.2	25.2	25.8	23.3
Y-03-02													
3'	Summer	17.3	19.4	13.9	--	--	--	20.0	21.5	17.0	18.7	21.6	16.3
	Fall	19.3	20.4	17.1	20.2	21.1	18.4	22.2	22.3	16.4	--	--	--
	Winter	15.8	19.1	12.5	--	--	--	20.4	22.4	10.8	--	--	--
	Spring	11.9	16.2	8.4	16.7	18.1	11.3	17.7	20.5	11.9	--	--	--
13'	Summer	19.6	21.0	18.0	--	--	--	20.9	22.1	19.7	21.7	22.5	20.5
	Fall	20.9	21.6	20.5	21.0	22.2	18.7	21.9	22.9	17.2	23.0	23.4	22.6
	Winter	19.7	20.6	18.7	--	--	--	21.8	22.8	20.1	23.8	24.9	24.4
	Spring	16.2	19.4	13.3	18.5	19.4	17.9	20.5	21.3	19.9	21.5	22.1	20.6
30'	Summer	19.8	21.2	18.1	--	--	--	21.2	22.2	19.9	22.2	22.8	20.9
	Fall	21.2	21.6	20.7	21.9	22.9	20.5	22.7	23.1	22.2	23.7	24.6	22.9
	Winter	20.3	21.4	19.1	--	--	--	22.6	23.3	21.2	24.6	25.1	23.3
	Spring	16.2	19.7	14.3	18.9	20.7	18.2	20.8	21.6	20.2	22.7	23.9	21.7

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
Y-04-02													
12'	Summer	16.0	18.1	14.3	17.5	19.4	16.1	19.1	20.5	17.3	20.0	21.1	19.5
	Fall	18.5	19.3	17.8	18.8	19.2	18.3	21.2	21.7	20.0	--	--	--
	Winter	16.6	18.7	14.7	17.8	19.7	15.9	21.3	22.6	17.7	22.8	23.9	20.8
	Spring	14.2	15.4	13.0	15.6	16.3	14.7	17.7	19.2	14.8	19.4	20.6	18.4
18'	Summer	16.9	18.4	14.9	18.0	19.9	16.7	19.7	20.7	18.6	20.4	21.1	19.7
	Fall	19.3	19.6	18.8	19.5	20.1	18.5	21.7	21.9	21.0	--	--	--
	Winter	18.4	19.8	16.7	19.4	20.5	18.4	22.0	22.5	20.0	23.5	24.1	22.1
	Spring	16.4	17.7	15.1	16.9	18.3	16.3	19.5	20.4	18.1	20.2	21.6	19.4
25'	Summer	17.7	19.4	15.7	18.3	20.2	16.9	20.1	21.0	18.9	20.6	21.1	20.0
	Fall	19.7	20.8	19.1	20.3	20.8	19.8	21.9	22.4	21.3	--	--	--
	Winter	19.1	20.8	17.3	20.1	21.0	18.4	22.3	22.8	20.8	23.7	24.2	22.1
	Spring	17.2	18.9	15.9	17.5	19.5	16.5	19.8	21.4	19.0	20.6	22.6	19.6
Y-05-01													
4'	Summer	14.4	16.5	13.1	13.2	15.9	10.0	16.5	18.1	13.3	17.6	20.0	15.9
	Fall	16.5	17.8	14.9	15.7	17.9	12.7	18.9	19.8	15.2	20.0	22.0	16.6
	Winter	13.7	15.9	10.1	10.5	12.5	6.7	20.2	20.5	5.6	21.7	22.3	11.3
	Spring	10.4	12.9	5.5	8.9	11.9	5.3	15.1	16.5	10.4	16.0	17.3	6.1
14'	Summer	16.9	18.4	10.5	17.3	18.4	16.0	18.5	20.2	17.1	19.5	20.1	18.9
	Fall	18.2	18.9	17.3	19.2	19.9	18.5	20.4	21.1	15.2	22.1	22.3	20.9
	Winter	17.8	19.5	15.8	18.3	19.9	17.8	21.1	21.8	19.5	22.9	23.2	20.7
	Spring	15.2	16.6	13.9	16.2	17.7	14.8	18.6	20.2	17.5	19.2	21.5	18.2
26'	Summer	17.2	18.8	15.7	18.2	19.5	16.9	19.3	20.4	18.3	19.8	20.6	18.5
	Fall	18.6	19.6	17.7	19.7	20.4	18.8	20.9	21.4	20.3	22.9	23.3	22.4
	Winter	18.1	20.1	16.1	19.6	20.6	18.1	21.5	22.0	20.2	23.0	23.5	21.0
	Spring	15.5	17.6	14.3	16.9	18.9	15.3	19.2	17.8	20.8	19.9	22.0	18.4

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
Y-06-01													
4'	Summer	10.9	13.3	8.5	10.9	14.3	8.6	16.5	17.1	15.2	14.5	15.0	13.3
	Fall	12.2	14.4	10.5	13.3	15.7	10.0	17.2	19.2	11.5	20.4	20.8	19.8
	Winter	8.0	10.7	6.2	8.3	11.3	5.5	18.5	19.3	6.8	19.7	20.8	5.6
	Spring	6.6	8.2	4.7	6.6	10.0	3.6	13.3	15.6	6.4	13.0	14.3	4.3
14'	Summer	13.8	15.9	11.9	14.7	16.9	12.8	17.4	17.9	17.4	17.7	18.7	17.0
	Fall	15.7	16.6	14.1	16.5	17.2	15.1	19.0	20.2	16.8	21.3	21.9	20.6
	Winter	13.9	15.6	11.2	15.2	16.9	12.7	20.0	20.8	14.7	21.6	21.9	17.3
	Spring	11.2	12.5	10.1	12.5	14.1	9.8	16.0	17.3	12.8	16.8	18.6	13.1
24'	Summer	14.5	16.4	12.6	15.6	17.4	13.3	18.0	18.9	17.4	18.0	18.8	16.8
	Fall	16.4	17.4	14.8	17.6	18.4	16.5	19.7	20.5	17.8	21.7	22.1	21.1
	Winter	15.4	17.9	12.1	16.7	19.0	13.6	20.0	20.6	16.5	21.5	22.2	18.3
	Spring	12.8	15.4	10.4	13.9	16.3	11.5	16.8	18.3	14.5	17.6	20.3	15.6
Y-07-02													
4'	Summer	9.7	11.4	7.7	11.5	13.2	8.4	14.0	15.0	11.4	14.8	16.2	13.2
	Fall	11.1	14.7	9.2	12.8	15.4	10.2	17.6	18.5	16.1	20.0	20.2	19.1
	Winter	6.6	11.1	4.6	7.6	10.2	4.1	16.1	18.8	3.3	19.1	20.2	3.1
	Spring	5.3	7.9	1.7	6.0	9.5	1.9	10.7	13.4	4.3	12.4	14.4	4.3
14'	Summer	11.7	14.0	9.3	12.9	15.3	10.1	15.4	16.4	13.8	--	--	--
	Fall	13.9	15.3	12.6	15.1	16.1	12.7	18.2	19.0	17.2	20.5	20.8	19.7
	Winter	11.0	14.2	7.2	13.0	15.7	11.0	18.4	19.1	14.5	20.5	21.0	14.4
	Spring	8.7	10.6	5.6	10.4	12.5	8.1	13.5	14.9	8.3	15.1	17.5	9.9

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
J-01-03													
1'	Summer	20.0	28.1	17.3	20.5	21.3	18.2	22.5	23.6	21.4	23.7	25.1	22.2
	Fall	22.1	23.0	20.9	23.7	24.6	21.7	24.2	25.4	22.1	26.6	27.2	25.8
	Winter	19.5	21.4	17.7	21.6	23.8	20.4	25.9	26.0	25.8	25.9	27.9	21.8
	Spring	15.9	20.9	9.8	18.4	21.1	15.2	21.8	22.6	20.5	22.1	23.1	19.2
20'	Summer	24.4	28.3	22.1	26.1	28.9	23.8	25.4	26.3	23.8	26.5	27.6	25.2
	Fall	24.5	25.8	23.5	25.6	26.6	24.6	26.1	27.1	25.0	26.8	28.2	26.0
	Winter	24.9	27.8	22.9	26.0	27.5	24.6	26.8	27.3	26.1	27.3	27.8	24.0
	Spring	25.2	28.8	21.9	26.0	28.8	23.8	24.1	25.8	23.0	25.6	29.2	25.1
72'	Summer	29.9	31.4	28.0	30.1	32.0	23.7	30.0	31.4	27.0	29.5	32.2	26.3
	Fall	29.0	31.1	26.5	29.4	31.4	27.4	29.3	32.1	27.0	28.5	30.9	26.2
	Winter	29.6	31.3	27.3	29.9	31.6	27.5	29.6	32.3	27.8	29.1	30.6	27.6
	Spring	30.3	31.7	27.2	30.9	32.4	29.5	29.7	31.3	27.1	29.6	31.7	26.9
J-02-03													
1'	Summer	16.4	19.6	11.0	17.0	19.1	13.3	21.2	23.9	14.7	21.5	24.4	14.6
	Fall	20.0	22.4	16.9	21.3	23.6	17.1	24.2	25.1	22.4	25.4	26.6	22.6
	Winter	14.2	19.3	9.5	19.0	20.4	11.1	23.7	25.0	11.5	26.4	27.5	15.6
	Spring	10.2	14.6	4.5	15.6	16.1	5.0	20.4	22.5	8.6	21.5	20.2	9.6
20'	Summer	21.9	23.4	20.3	22.8	25.2	21.2	24.2	25.2	22.9	25.1	26.1	23.3
	Fall	23.2	24.3	22.8	24.7	25.6	23.8	25.2	25.6	24.8	26.7	27.9	25.5
	Winter	20.6	22.6	19.4	23.4	26.0	21.7	25.5	25.8	21.5	27.6	28.0	25.9
	Spring	20.5	22.7	18.4	21.3	23.0	19.0	22.7	24.6	20.9	25.0	25.8	24.1
43'	Summer	24.0	27.1	21.1	25.2	28.3	22.1	25.7	27.5	23.2	26.4	28.6	23.8
	Fall	24.6	27.5	22.5	26.0	29.0	24.1	25.7	27.0	24.8	27.0	28.4	25.7
	Winter	23.9	27.5	22.5	25.5	28.6	22.3	25.7	27.1	22.8	28.0	28.4	27.2
	Spring	23.2	26.8	20.1	23.5	27.7	20.9	24.3	27.5	22.1	26.2	28.5	24.0

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
J-03-02													
1'	Summer	12.7	15.1	9.7	10.8	13.1	6.1	17.8	19.9	12.1	18.6	22.1	12.5
	Fall	16.1	17.8	14.4	15.4	17.3	11.0	20.9	21.8	19.3	22.7	23.7	19.0
	Winter	11.1	14.2	7.3	10.7	14.8	5.9	21.2	22.3	9.3	23.4	24.4	11.9
	Spring	6.8	9.0	3.9	6.3	8.8	3.2	14.9	18.5	5.8	16.0	19.0	6.1
13'	Summer	17.5	20.4	13.4	16.7	20.9	13.3	20.4	21.7	18.0	22.0	23.9	18.7
	Fall	19.5	22.0	17.1	20.2	21.1	18.0	21.7	22.1	21.0	23.0	24.0	21.3
	Winter	15.9	18.6	12.5	17.4	20.6	12.7	20.8	22.9	14.2	23.3	24.9	16.5
	Spring	12.7	17.1	9.1	13.5	18.1	3.2	18.5	20.4	13.1	19.7	22.6	17.7
20'	Summer	18.7	21.8	13.7	18.1	22.5	13.3	20.7	22.7	18.1	22.1	24.3	18.7
	Fall	19.7	22.0	17.1	20.8	23.1	18.2	21.6	22.2	21.0	23.0	24.2	21.0
	Winter	18.2	21.9	12.6	20.1	24.1	13.8	22.4	23.0	13.9	22.8	25.1	16.6
	Spring	15.9	20.0	9.3	16.0	21.5	9.4	19.6	22.6	13.7	20.7	24.5	17.5
J-04-02													
1'	Summer	5.5	8.7	2.9	7.4	9.2	6.2	9.6	12.1	8.2	--	--	--
	Fall	8.7	11.7	6.3	3.8	5.4	1.1	14.2	15.4	11.5	--	--	--
	Winter	3.2	6.0	1.2	5.7	6.7	3.4	14.0	15.9	3.6	--	--	--
	Spring	1.6	3.0	0.3	1.7	3.3	0.3	6.2	10.2	0.7	--	--	--
13'	Summer	7.4	10.2	4.9	7.1	7.7	6.5	11.9	14.9	8.7	13.4	16.2	9.3
	Fall	10.5	12.2	8.6	4.2	7.0	1.3	15.5	15.8	14.7	16.9	17.6	15.9
	Winter	4.5	7.9	1.9	6.5	9.8	3.8	14.9	16.6	4.2	6.5	7.0	6.2
	Spring	2.5	3.0	0.4	0.0	1.0	0.2	7.9	11.3	1.5	5.9	8.9	2.6
20'	Summer	8.4	11.1	5.5	9.3	13.4	6.3	12.7	15.9	10.4	14.4	16.4	11.3
	Fall	11.2	12.6	9.1	13.0	14.2	11.9	15.8	16.2	15.0	17.9	19.0	16.6
	Winter	5.5	9.1	2.3	8.6	14.7	4.5	15.0	16.6	4.4	19.1	19.5	6.1
	Spring	3.2	6.8	0.4	3.9	9.1	0.3	9.1	12.0	1.5	9.9	12.9	2.9

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
J-05-02													
1'	Summer	1.6	2.8	0.7	2.3	3.9	1.1	6.5	8.6	4.0	7.4	10.1	2.8
	Fall	4.1	5.2	2.1	5.3	7.2	3.4	10.6	11.5	9.1	12.4	13.7	10.6
	Winter	0.6	1.5	0.2	0.5	1.3	0.2	10.0	11.4	0.4	12.9	14.8	1.1
	Spring	0.2	0.4	2.8	0.4	1.0	0.1	2.2	5.0	0.0	3.7	6.9	0.0
20'	Summer	2.2	3.7	0.9	3.3	5.8	1.6	7.8	10.4	5.1	9.2	11.9	5.6
	Fall	5.1	6.6	2.1	6.4	7.4	4.5	11.8	12.3	11.1	13.8	14.9	12.4
	Winter	0.8	2.5	0.2	0.7	1.8	0.2	11.0	12.4	0.5	15.3	16.0	1.1
	Spring	0.2	0.5	0.0	0.6	1.5	0.2	2.8	6.3	0.0	3.7	7.7	0.1
39'	Summer	2.5	4.7	1.4	3.7	6.5	1.8	8.5	10.9	5.7	9.8	12.4	6.3
	Fall	5.5	6.9	4.0	7.0	8.6	5.1	12.2	12.7	11.3	14.1	15.2	12.8
	Winter	0.9	2.6	0.2	1.1	2.3	0.2	11.3	12.7	0.5	13.1	16.3	1.6
	Spring	0.2	0.6	0.1	0.6	2.0	0.1	3.6	6.7	0.2	5.0	8.3	0.2
J-06-01													
3'	Summer	0.29	0.3	0.2	0.1	0.5	0.0	1.6	3.4	0.1	3.0	5.4	0.2
	Fall	0.6	1.1	0.2	1.1	2.2	0.1	5.4	6.1	3.3	7.5	8.1	5.7
	Winter	0.1	0.1	0.1	0.3	0.7	0.0	5.0	6.7	0.0	8.0	10.0	0.2
	Spring	0.1	0.3	0.0	0.1	0.4	0.0	0.2	0.6	0.0	0.6	1.7	0.0
13'	Summer	0.27	0.3	0.2	0.2	0.8	0.0	2.4	5.6	0.1	4.3	6.9	0.5
	Fall	1.0	1.8	0.2	1.8	3.1	0.2	7.0	7.8	4.3	9.0	10.0	7.1
	Winter	0.1	0.1	0.1	0.2	0.2	0.0	6.3	8.3	0.2	9.7	11.3	0.1
	Spring	0.1	0.3	0.0	0.1	0.2	0.1	0.4	1.4	0.0	0.8	2.7	0.0
23'	Summer	0.3	0.5	0.2	0.3	1.2	0.0	2.8	6.4	0.1	5.2	7.9	1.0
	Fall	1.4	2.4	0.4	2.4	3.6	0.5	7.6	8.4	5.5	10.1	10.9	8.7
	Winter	0.1	0.1	0.1	0.2	0.2	0.1	6.8	9.0	0.1	10.4	12.2	0.1
	Spring	0.1	0.3	0.0	0.1	0.2	0.1	0.5	1.8	0.0	1.1	3.3	0.0

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ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
J-07-01													
3'	Summer	0.3	0.6	0.2	0.1	0.3	0.0	0.1	0.3	0.1	1.6	3.5	0.0
	Fall	0.2	0.2	0.2	0.2	0.9	0.0	3.7	4.2	3.1	5.2	5.9	3.8
	Winter	0.2	0.2	0.1	0.2	0.4	0.1	3.3	4.7	0.0	5.5	7.3	0.5
	Spring	0.2	0.3	0.1	0.2	0.5	0.1	0.05	0.1	0.0	0.07	0.1	0.0
13'	Summer	0.2	0.3	0.2	0.02	0.1	0.0	0.9	2.8	0.0	1.8	4.2	.0
	Fall	0.3	0.3	0.2	0.15	0.6	0.0	4.3	4.8	3.4	5.6	6.2	4.4
	Winter	0.1	0.1	0.1	0.11	0.2	0.1	4.0	5.2	0.0	6.1	8.1	0.1
	Spring	0.1	0.3	0.0	0.08	0.2	0.0	0.05	0.1	0.0	0.08	0.1	0.0
28'	Summer	0.3	0.3	0.2	0.07	0.1	0.0	1.0	3.1	0.1	2.1	4.4	0.0
	Fall	0.2	0.3	0.2	0.2	0.7	0.0	4.6	5.1	4.0	6.2	7.6	5.2
	Winter	0.1	0.1	0.1	0.09	0.1	0.0	4.2	5.6	0.0	6.4	8.7	0.1
	Spring	0.1	0.3	0.0	0.02	0.1	0.0	0.05	0.1	0.0	0.1	0.3	0.0
J-08-01													
5'	Summer	0.2	0.4	0.1	0.05	0.3	0.0	0.1	0.1	0.1	0.5	1.6	0.0
	Fall	0.0	0.1	0.0	0.26	0.6	0.2	1.7	2.1	1.1	2.8	3.4	1.9
	Winter	0.1	0.1	0.0	0.15	0.3	0.0	1.5	2.4	0.0	3.3	4.8	0.1
	Spring	0.2	0.3	0.1	0.15	0.3	0.0	0.1	0.4	0.0	0.1	0.1	0.0
15'	Summer	0.1	0.1	0.0	0.02	0.1	0.0	0.2	0.8	0.1	0.5	1.5	0.0
	Fall	0.0	0.0	0.0	0.24	0.4	0.2	1.7	2.1	0.9	3.1	4.0	2.1
	Winter	0.1	0.1	0.0	0.19	0.2	0.1	1.6	2.4	0.0	3.5	5.1	0.1
	Spring	0.1	0.3	0.0	0.05	0.1	0.0	0.03	0.1	0.0	0.1	0.1	0.0
25'	Summer	0.1	0.1	0.0	0.08	0.1	0.0	0.2	0.7	0.1	0.5	1.5	0.0
	Fall	0.0	0.1	0.0	0.18	0.2	0.1	1.7	2.2	0.9	3.1	4.0	2.1
	Winter	0.1	0.1	0.0	0.20	0.2	0.0	1.6	2.4	0.0	3.7	4.6	0.1
	Spring	0.1	0.3	0.0	0.11	0.2	0.0	0.0	0.0	0.0	0.1	0.2	0.0

ATTACHMENT D-1 (Cont'd)

SEASONAL AVERAGE SALINITIES AND WEEKLY EXTREMES (PPT)

		LONG TERM AVERAGE CONDITIONS						DROUGHT CONDITIONS					
		BASE			FUTURE			BASE			FUTURE		
STATION/ DEPTH	SEASON	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK	SEASONAL AVERAGE	HIGH WEEK	LOW WEEK
J-09-01													
2'	Summer	0.1	0.1	0.0	0.12	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0
	Fall	0.0	0.1	0.0	0.04	0.3	0.0	0.2	0.5	0.0	0.9	1.0	0.5
	Winter	0.0	0.0	0.0	0.4	0.9	0.2	0.2	0.2	0.0	0.9	1.6	0.0
	Spring	0.2	0.3	0.0	0.03	0.1	0.0	0.1	0.1	0.0	0.1	0.2	0.0
16'	Summer	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.3	0.0	0.0	0.0	0.0
	Fall	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.6	0.0	1.0	1.1	0.6
	Winter	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.4	0.0	1.0	1.9	0.0
	Spring	0.1	0.3	0.0	0.1	0.2	0.0	0.1	0.1	0.0	0.1	0.2	0.0
29'	Summer	0.1	0.1	0.1	0.05	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0
	Fall	0.1	0.3	0.1	0.1	0.1	0.1	0.3	0.7	0.0	1.0	1.3	0.4
	Winter	0.0	0.0	0.0	0.2	0.6	0.0	0.3	0.5	0.0	1.0	1.8	0.0
	Spring	0.2	0.3	0.0	0.2	0.2	0.2	0.1	0.3	0.0	0.1	0.2	0.0
J-10-01													
2'	Summer	0.1	0.1	0.0	0.1	0.4	0.0	0.4	0.7	0.0	0.0	0.3	0.0
	Fall	0.1	0.3	0.0	0.2	0.4	0.2	0.1	0.1	0.0	0.2	0.3	0.1
	Winter	0.0	0.0	0.0	0.3	0.5	0.2	0.1	0.2	0.1	0.3	0.7	0.0
	Spring	0.1	0.3	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.0
13'	Summer	0.1	0.1	0.0	0.1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0
	Fall	0.0	0.0	0.0	0.2	0.2	0.1	0.1	0.1	0.0	0.2	0.5	0.0
	Winter	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.4	0.0
	Spring	0.2	0.3	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.0
24'	Summer	0.1	0.1	0.0	0.1	0.2	0.1	0.05	0.1	0.0	0.0	0.0	0.0
	Fall	0.05	0.1	0.0	0.2	0.2	0.1	0.1	0.1	0.0	0.2	0.3	0.1
	Winter	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.6	0.0
	Spring	0.1	0.3	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.0

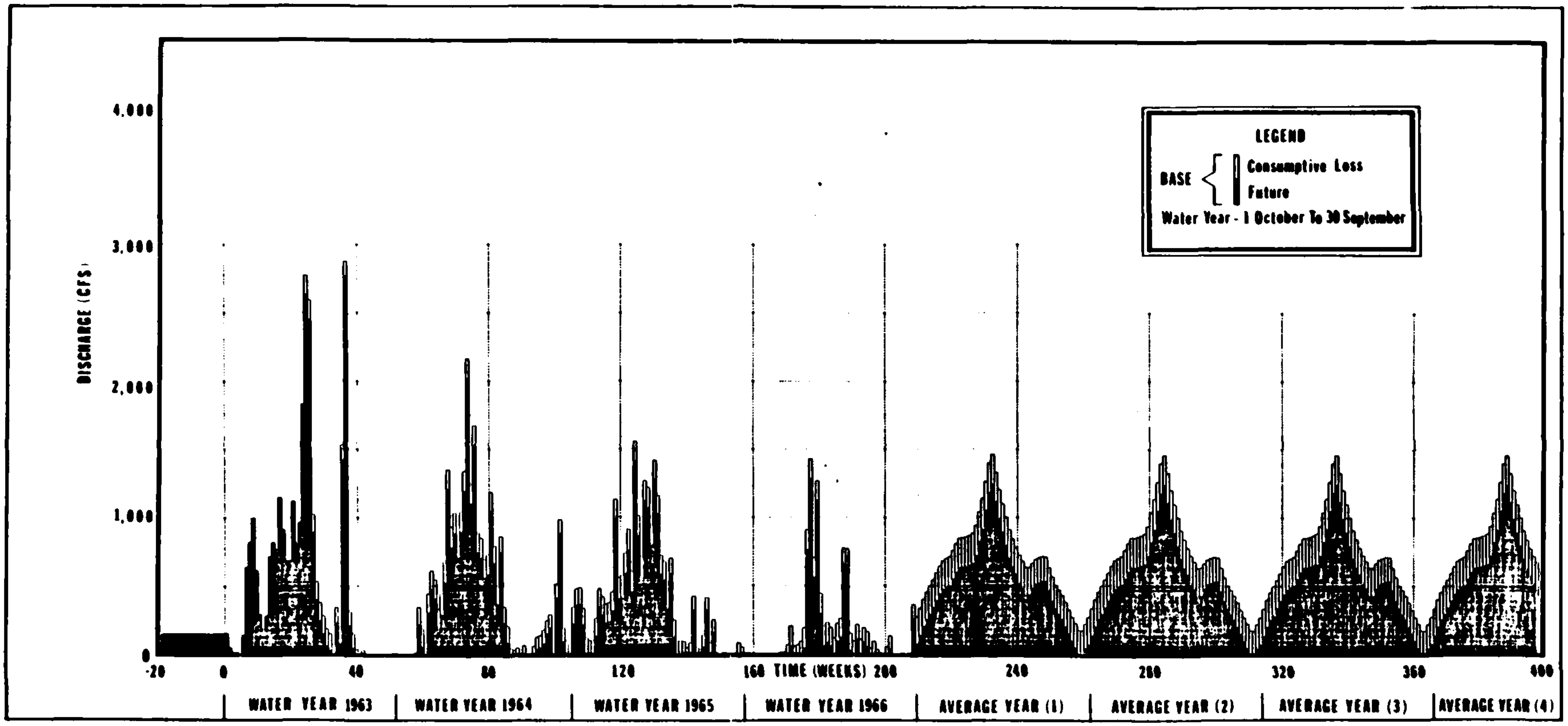


PLATE D-1 INFLOW HYDROGRAPH, INFLOW POINT 1, NANSEMOND RIVER

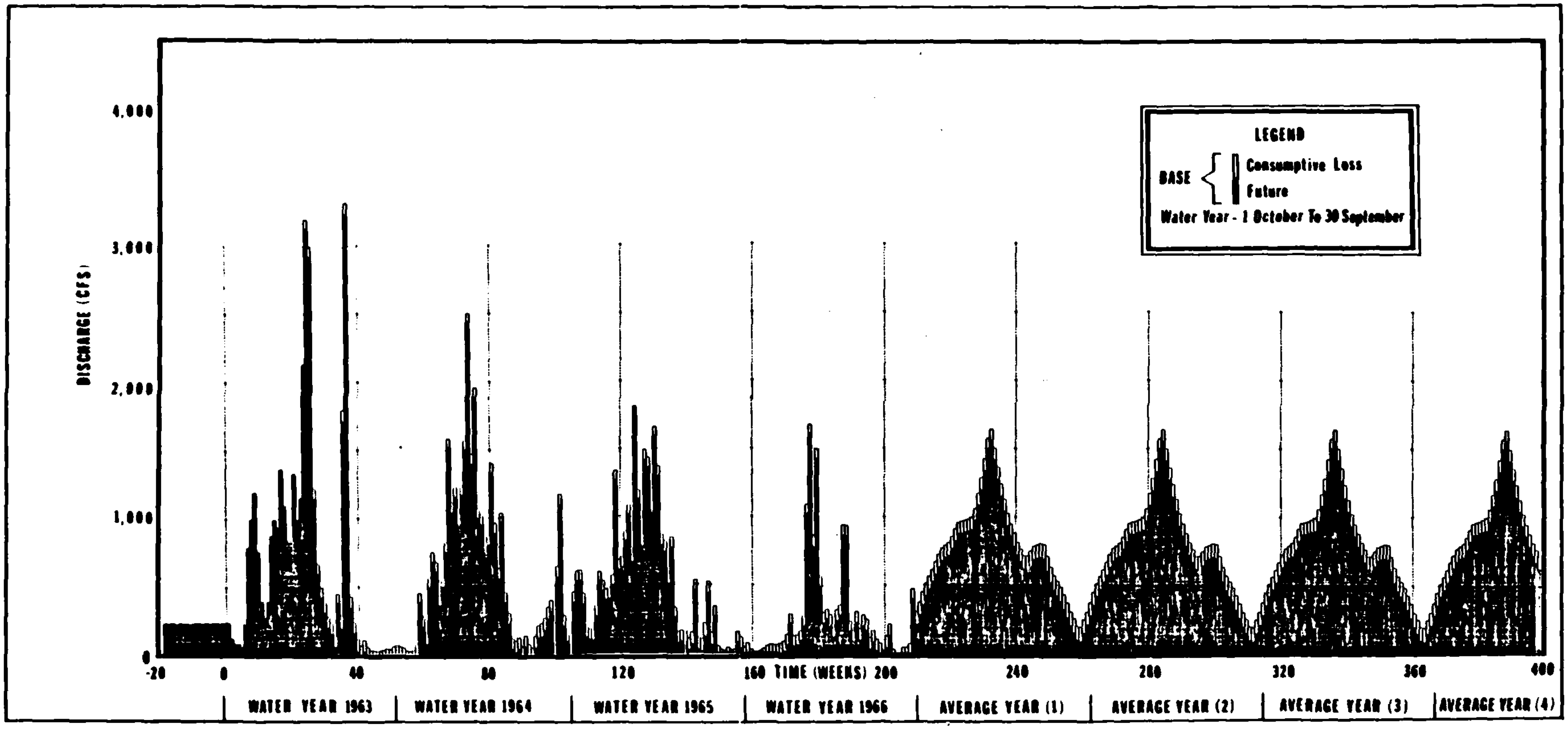


PLATE D-2 INFLOW HYDROGRAPH, INFLOW POINT 2, CHICKAHOMINY RIVER

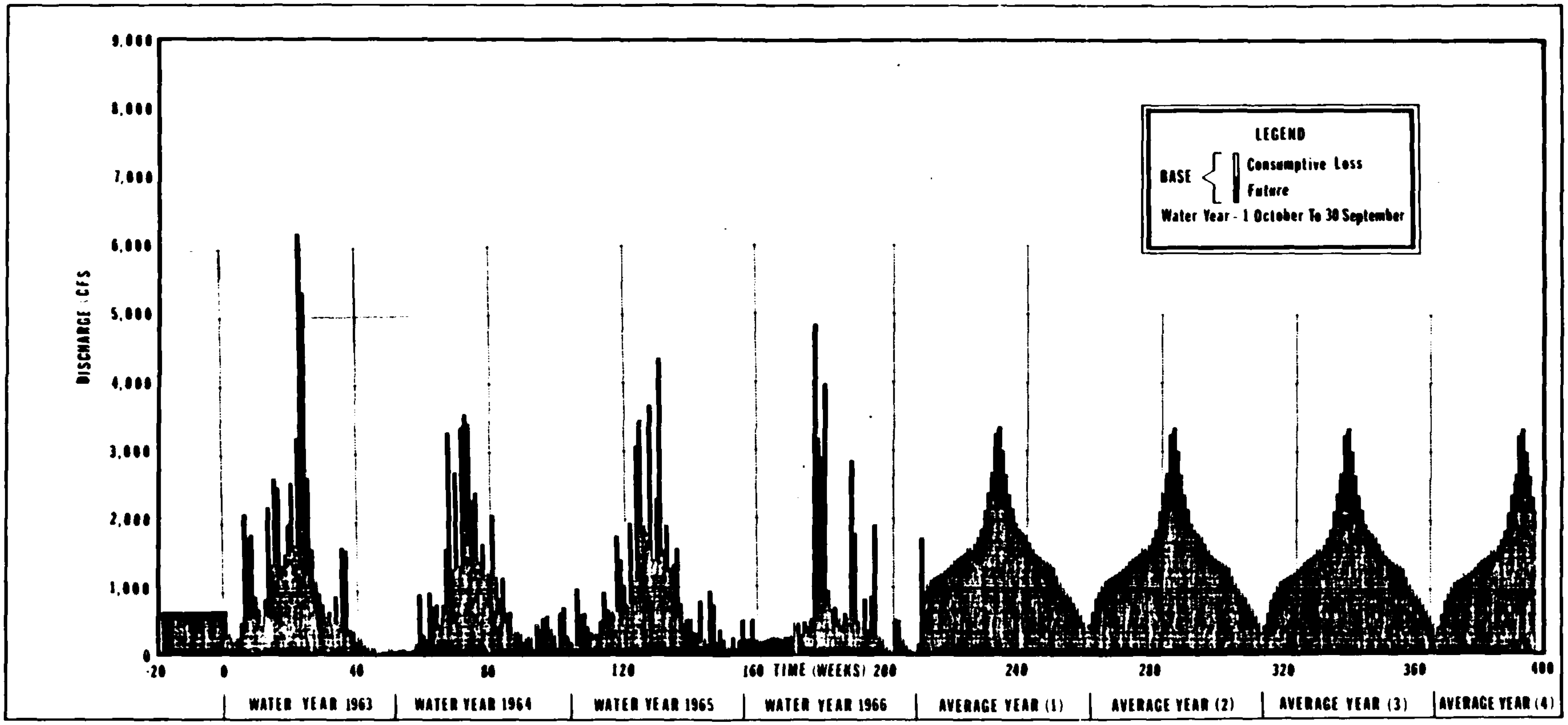


PLATE D-3 INFLOW HYDROGRAPH, INFLOW POINT 3, APPOMATTOX RIVER

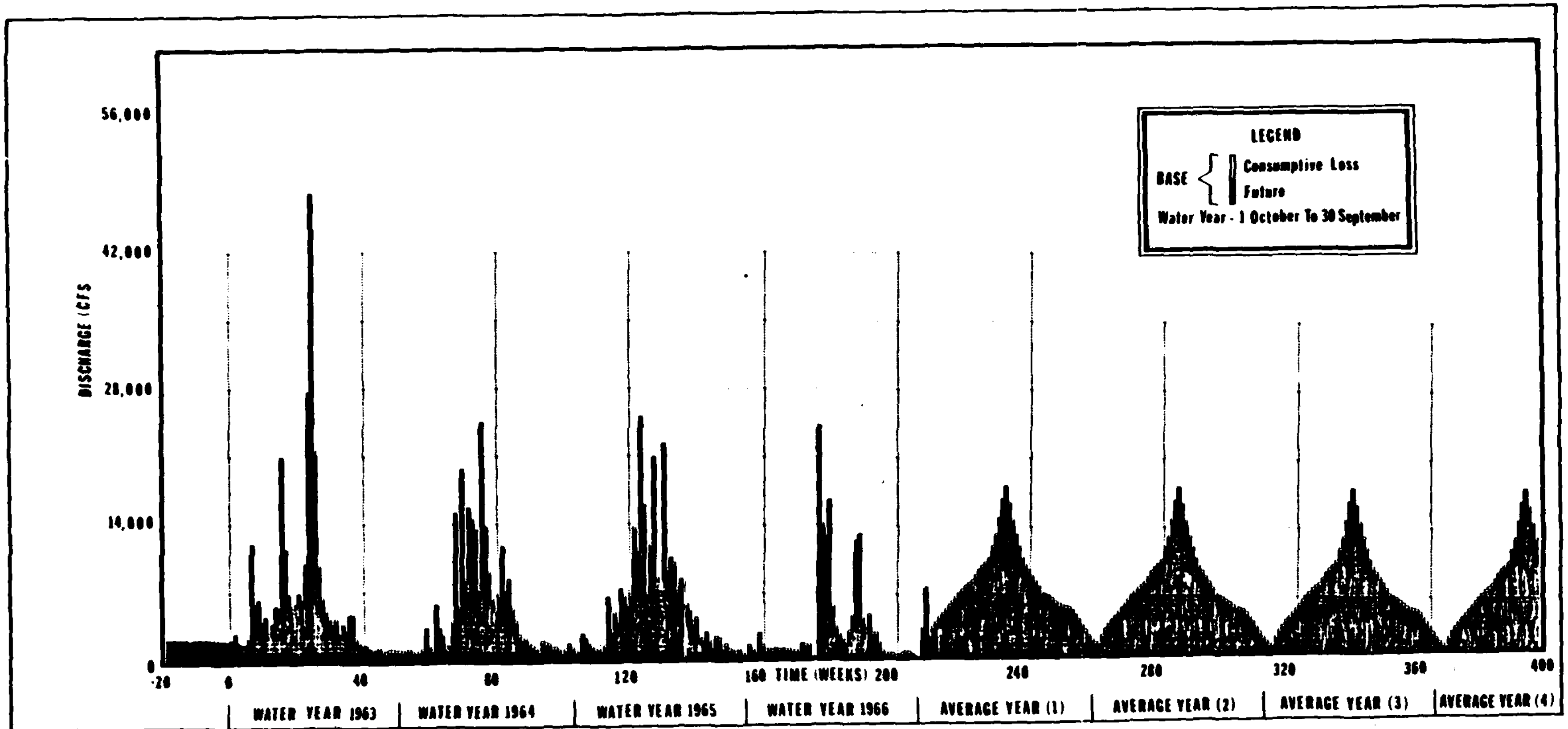


PLATE D- 4 INFLOW HYDROGRAPH, INFLOW POINT 4, JAMES RIVER (ABOVE RICHMOND)

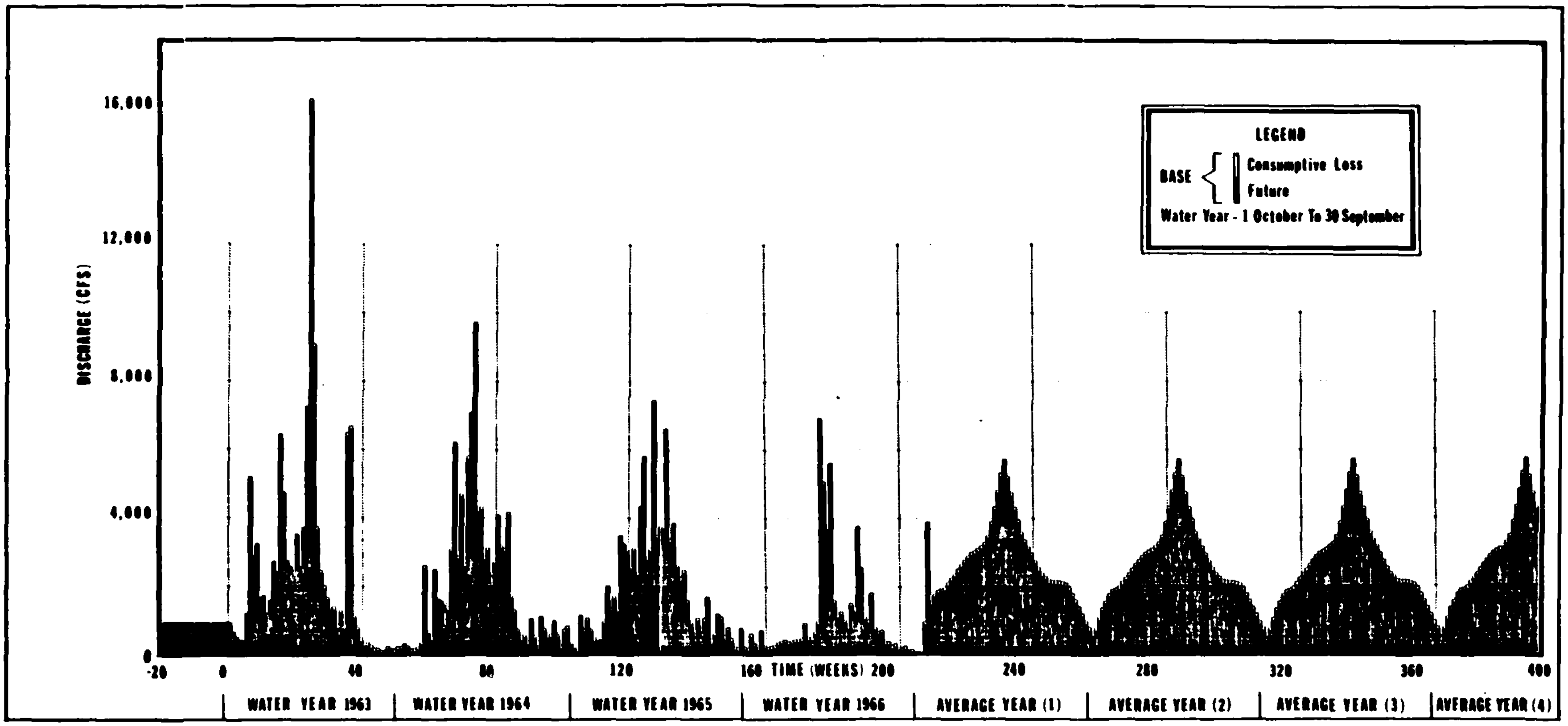


PLATE D-5 INFLOW HYDROGRAPH, INFLOW POINT 5, YORK RIVER

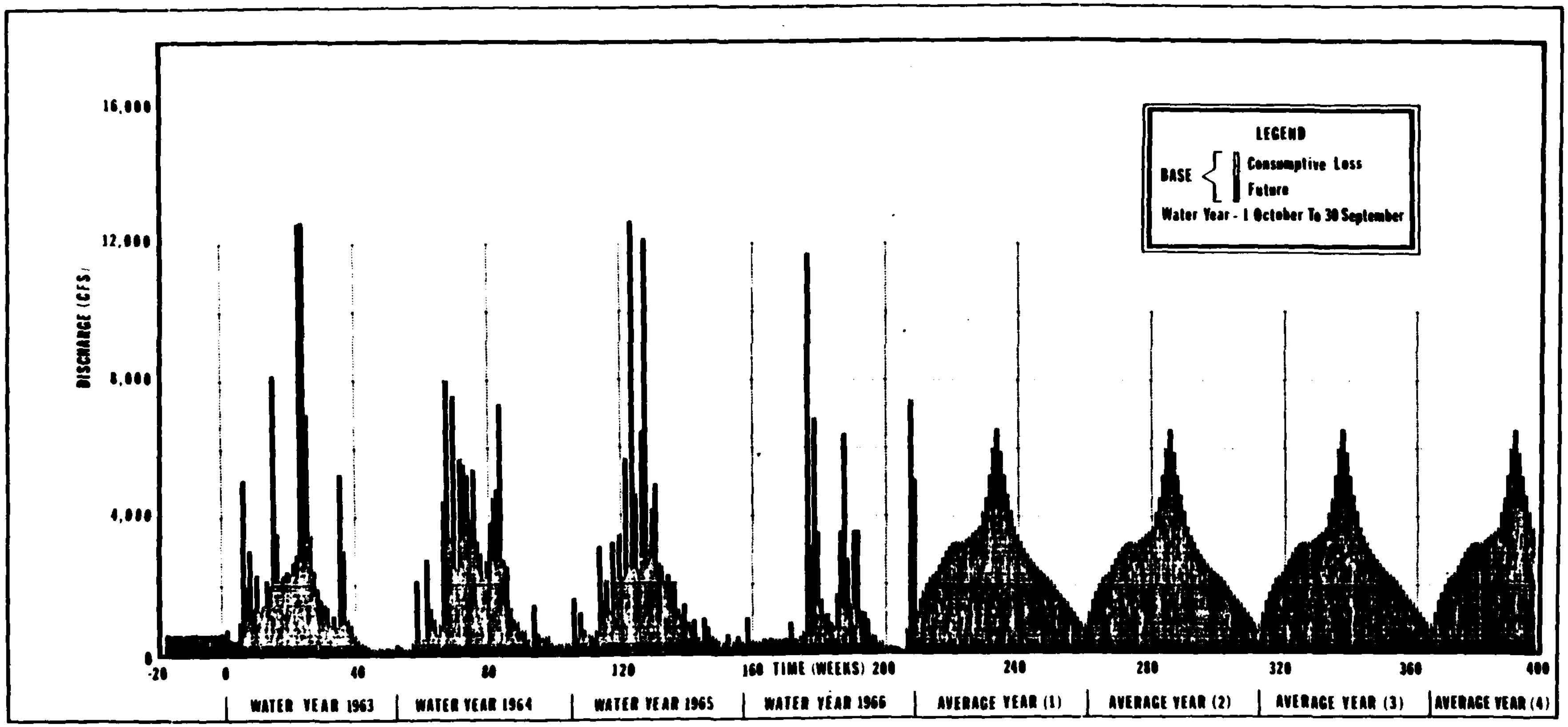


PLATE D- 6 INFLOW HYDROGRAPH, INFLOW POINT 6, RAPPAHANNOCK RIVER

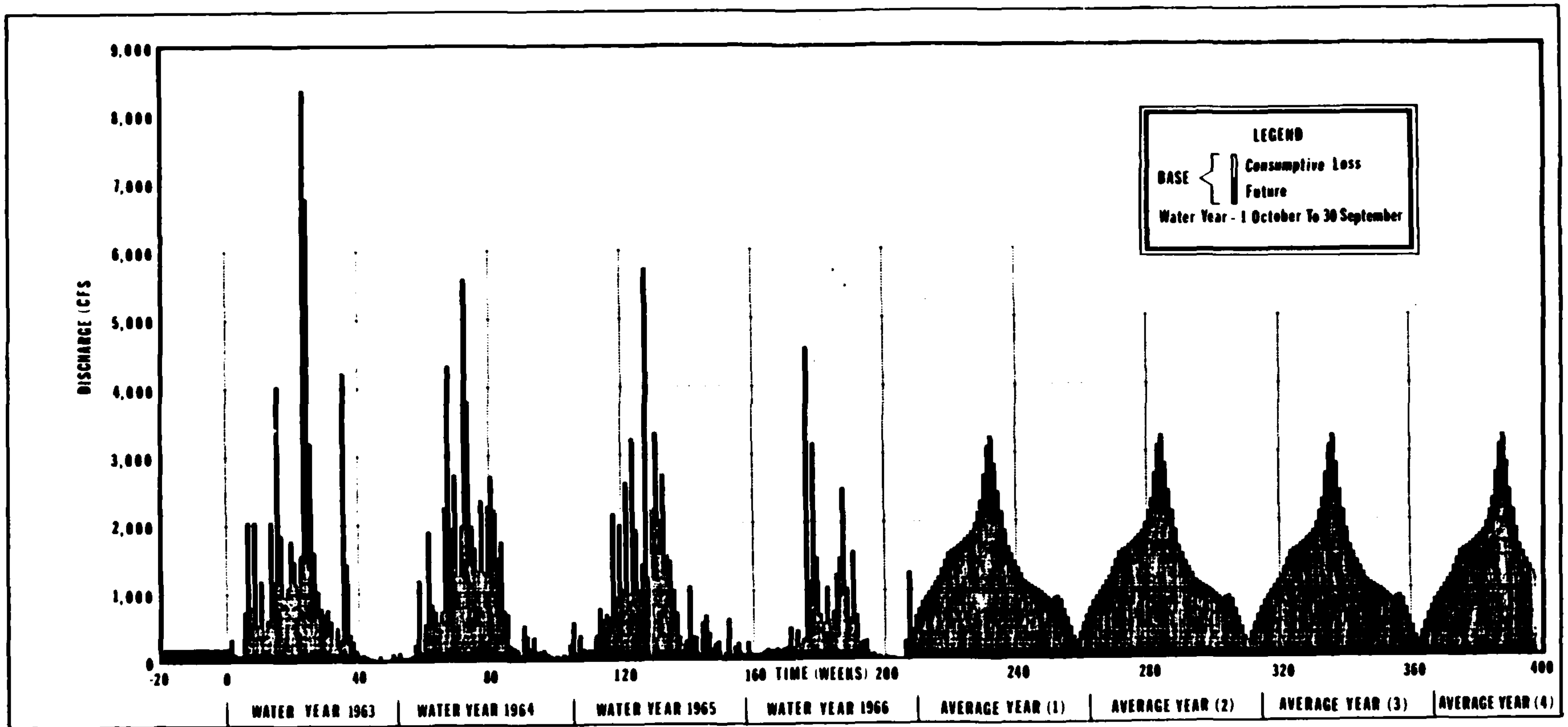


PLATE D-7 INFLOW HYDROGRAPH, INFLOW POINT 7, LOWER POTOMAC RIVER (WICOMICO)

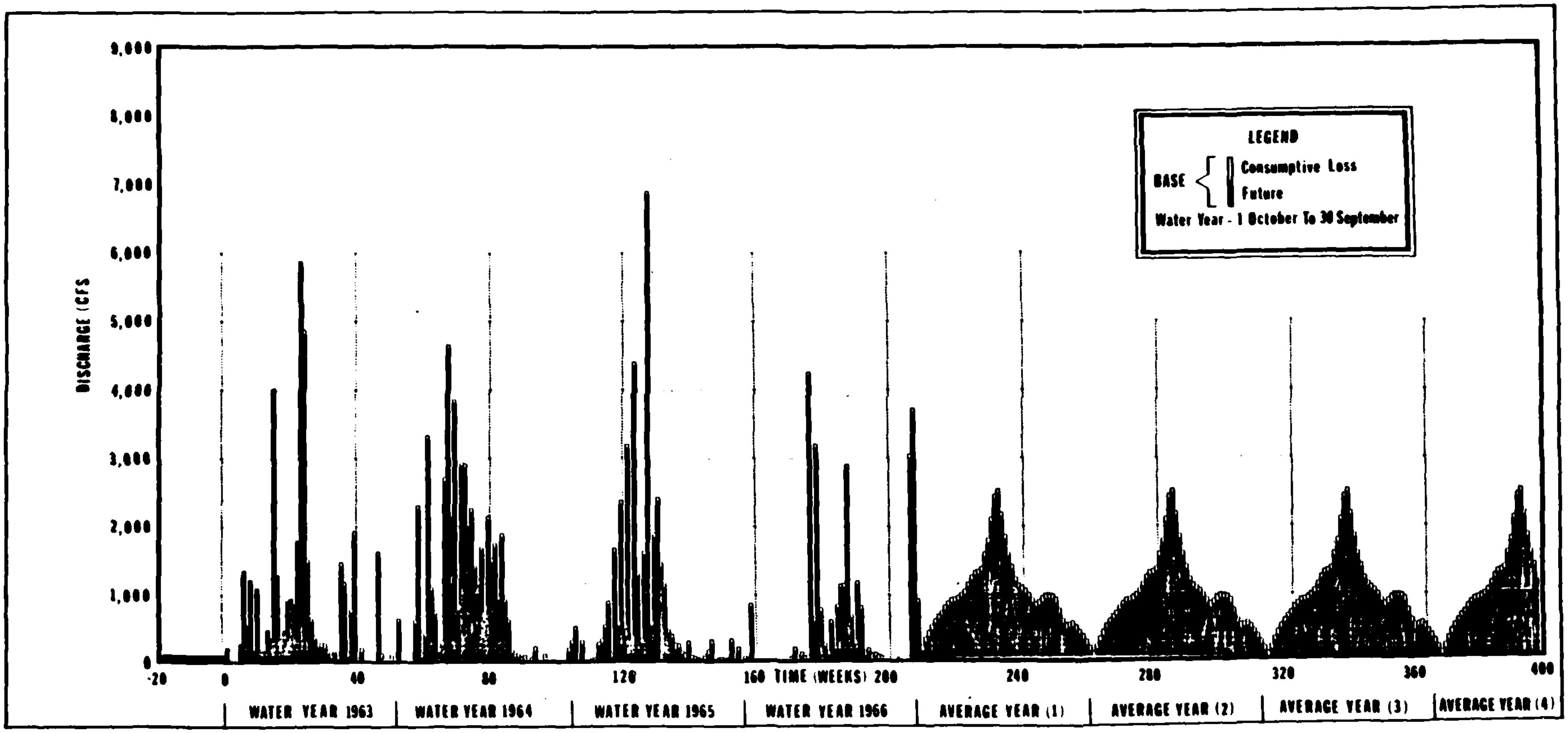


PLATE D- 8 INFLOW HYDROGRAPH, INFLOW POINT 8, OCCOQUAN RIVER

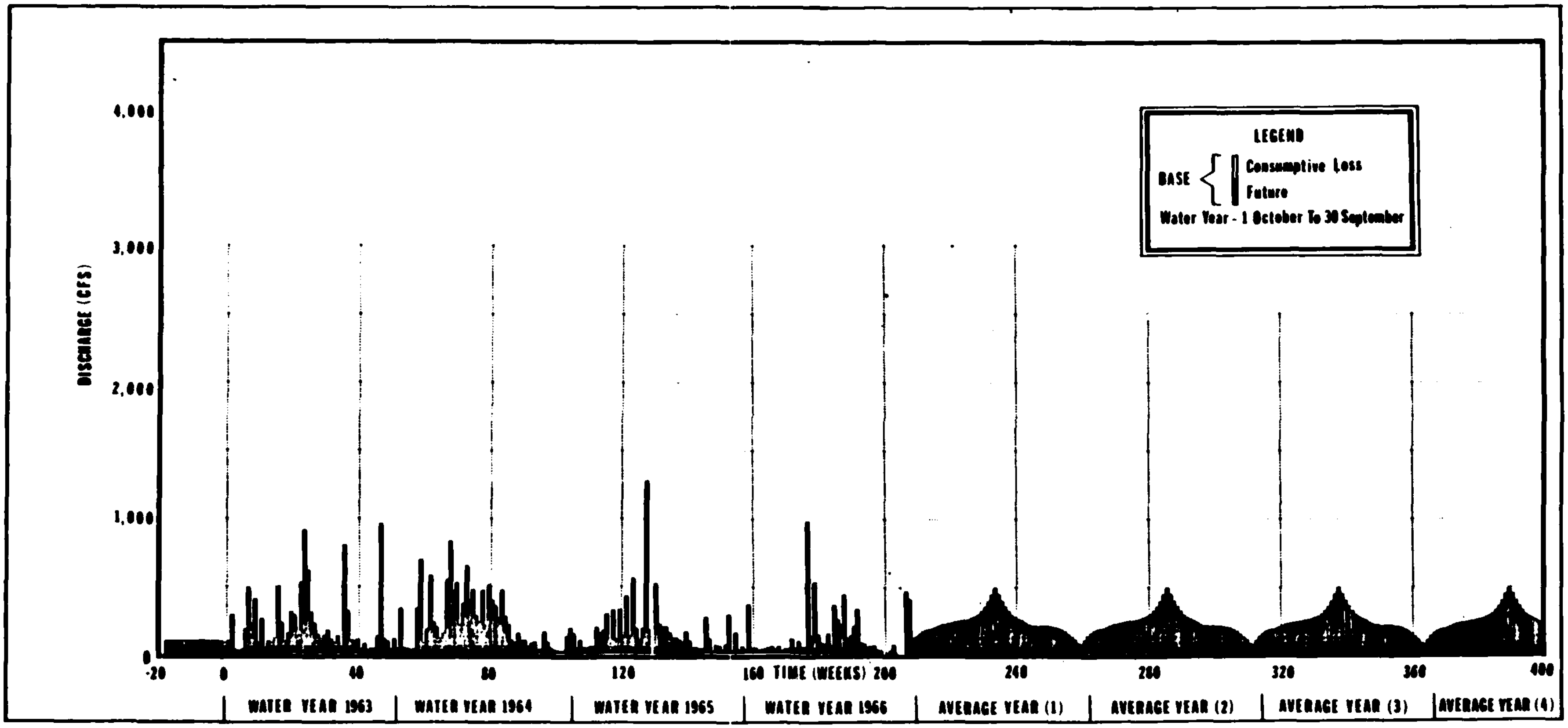


PLATE D- 9 INFLOW HYDROGRAPH, INFLOW POINT 9, ANACOSTIA RIVER

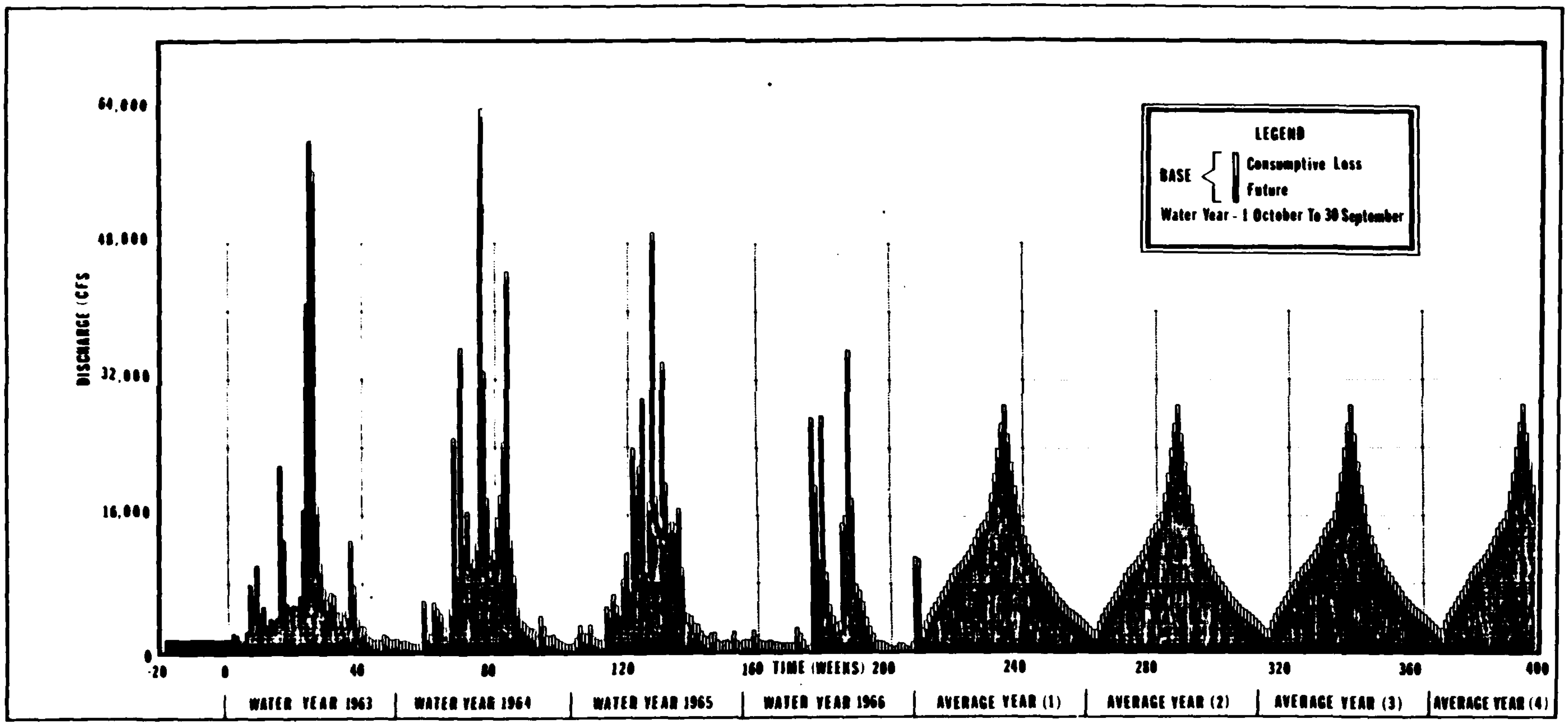


PLATE D-10 INFLOW HYDROGRAPH, INFLOW POINT 10, POTOMAC RIVER (ABOVE WASHINGTON)

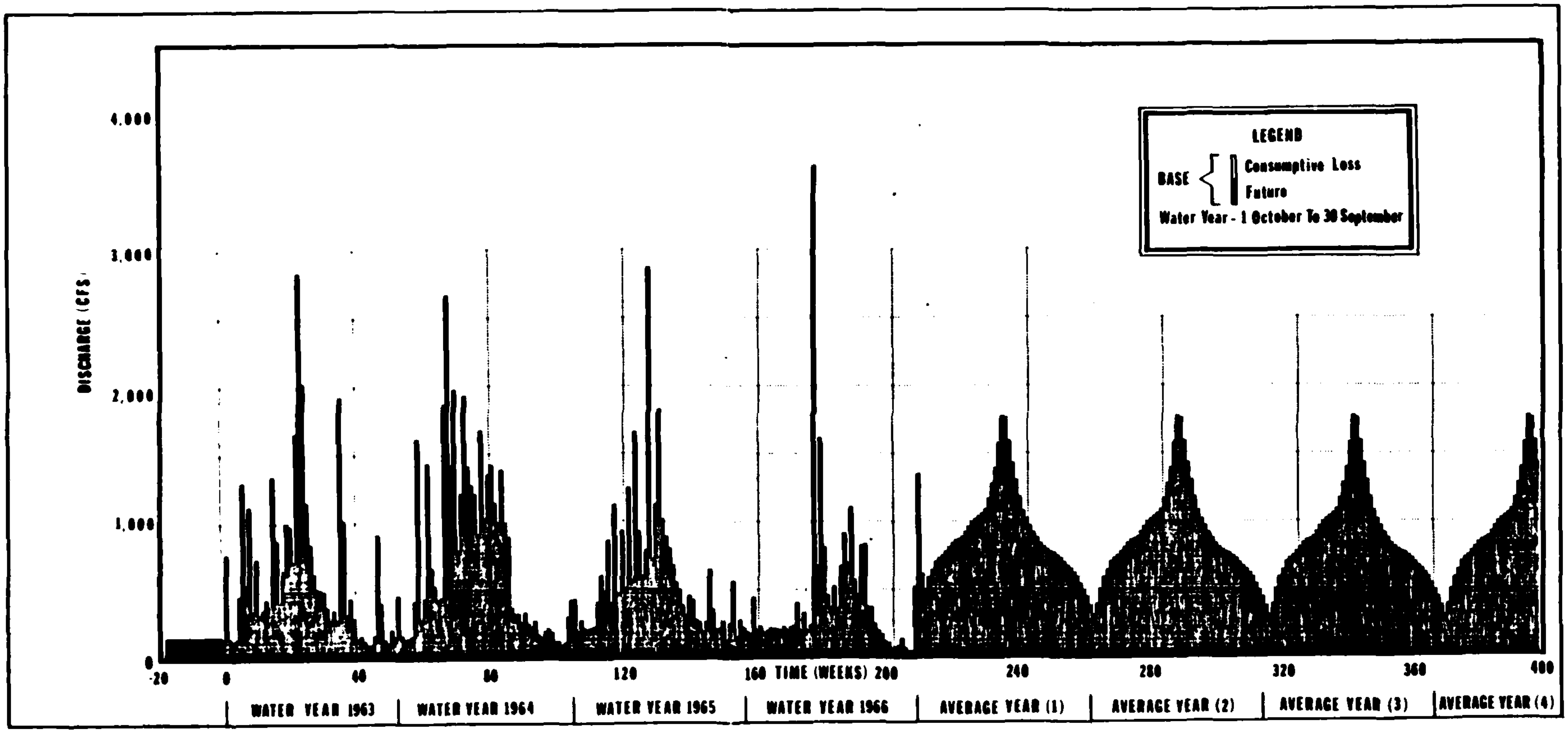


PLATE D-11 INFLOW HYDROGRAPH, INFLOW POINT 11, PATUXENT RIVER

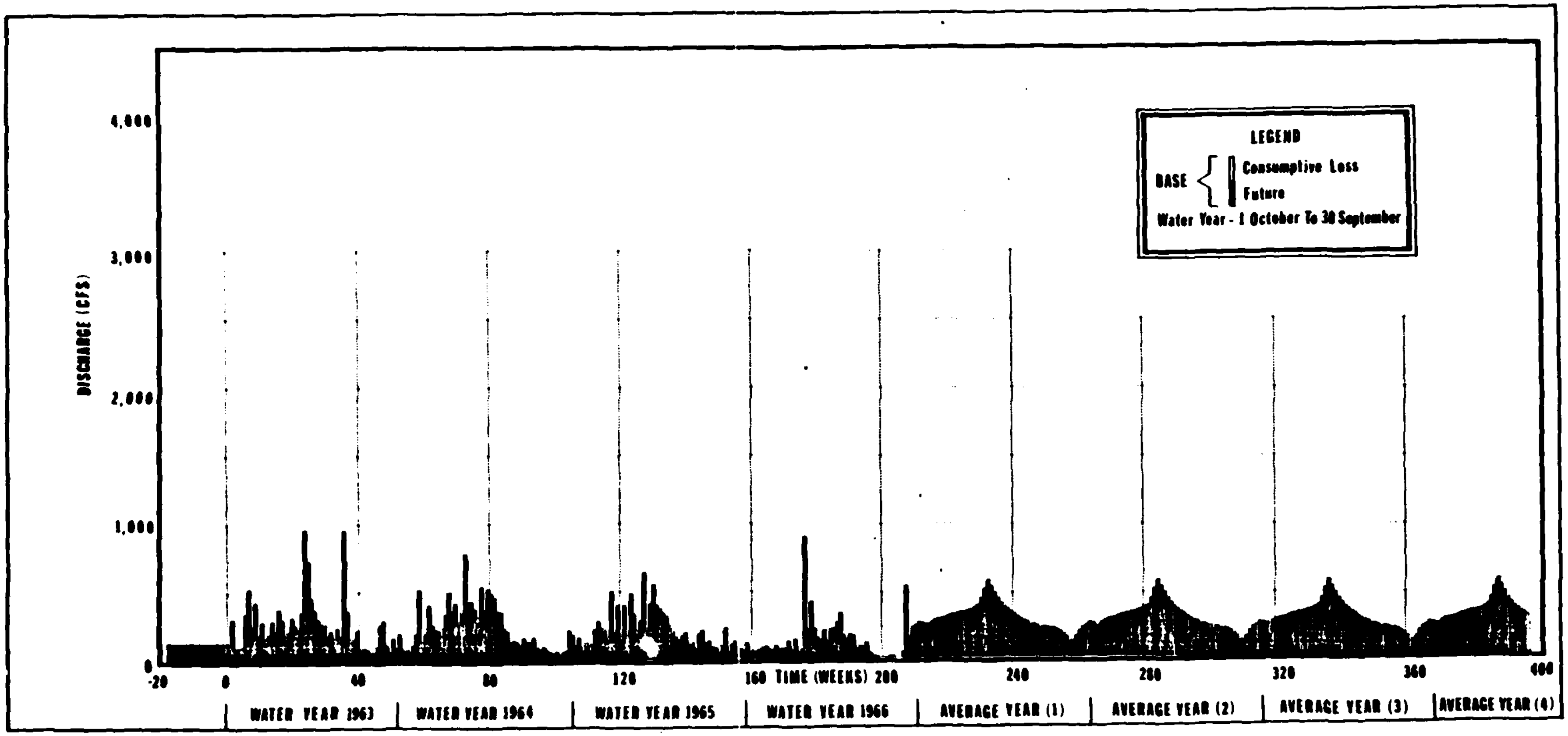


PLATE D-12 INFLOW HYDROGRAPH, INFLOW POINT 12, SEVERN RIVER

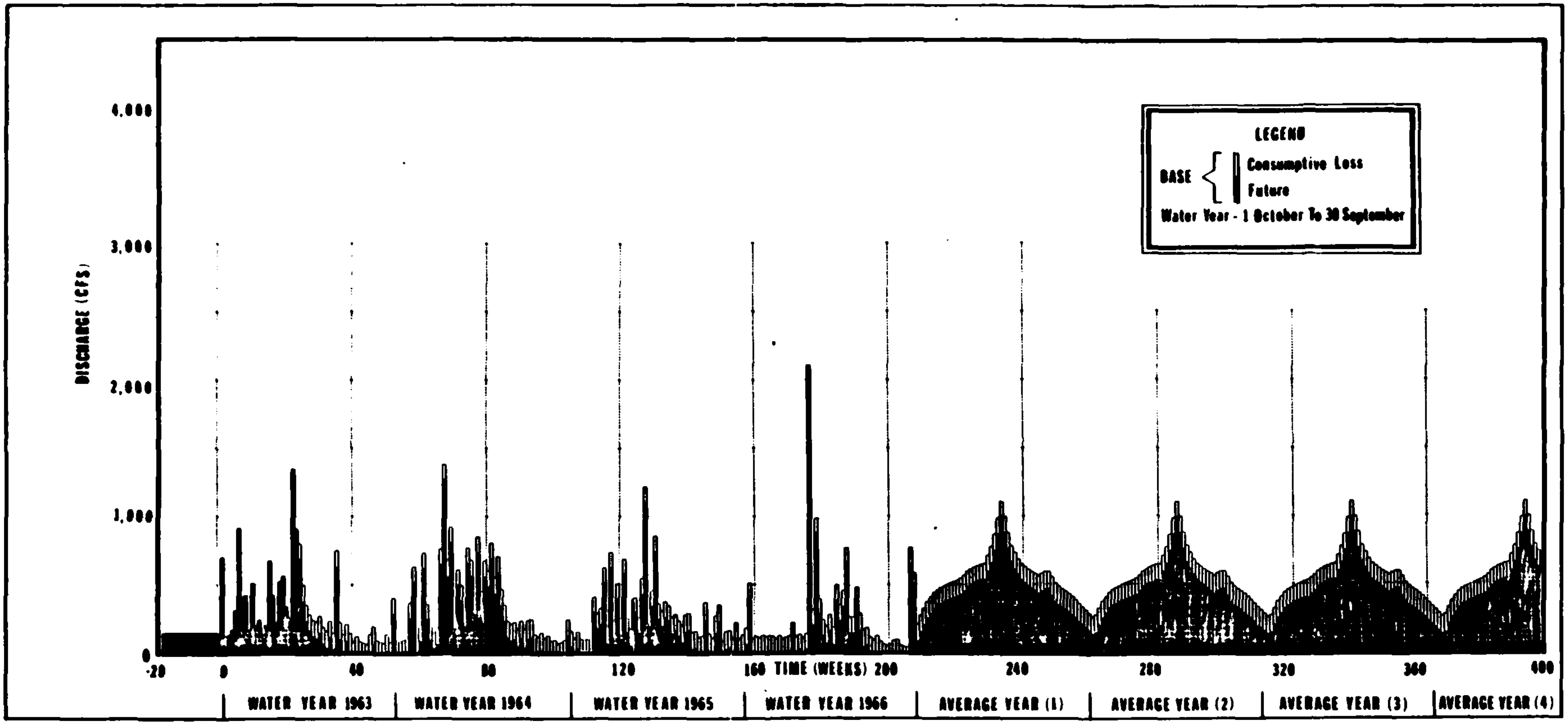


PLATE D-13 INFLOW HYDROGRAPH, INFLOW POINT 13, PATAPSCO RIVER

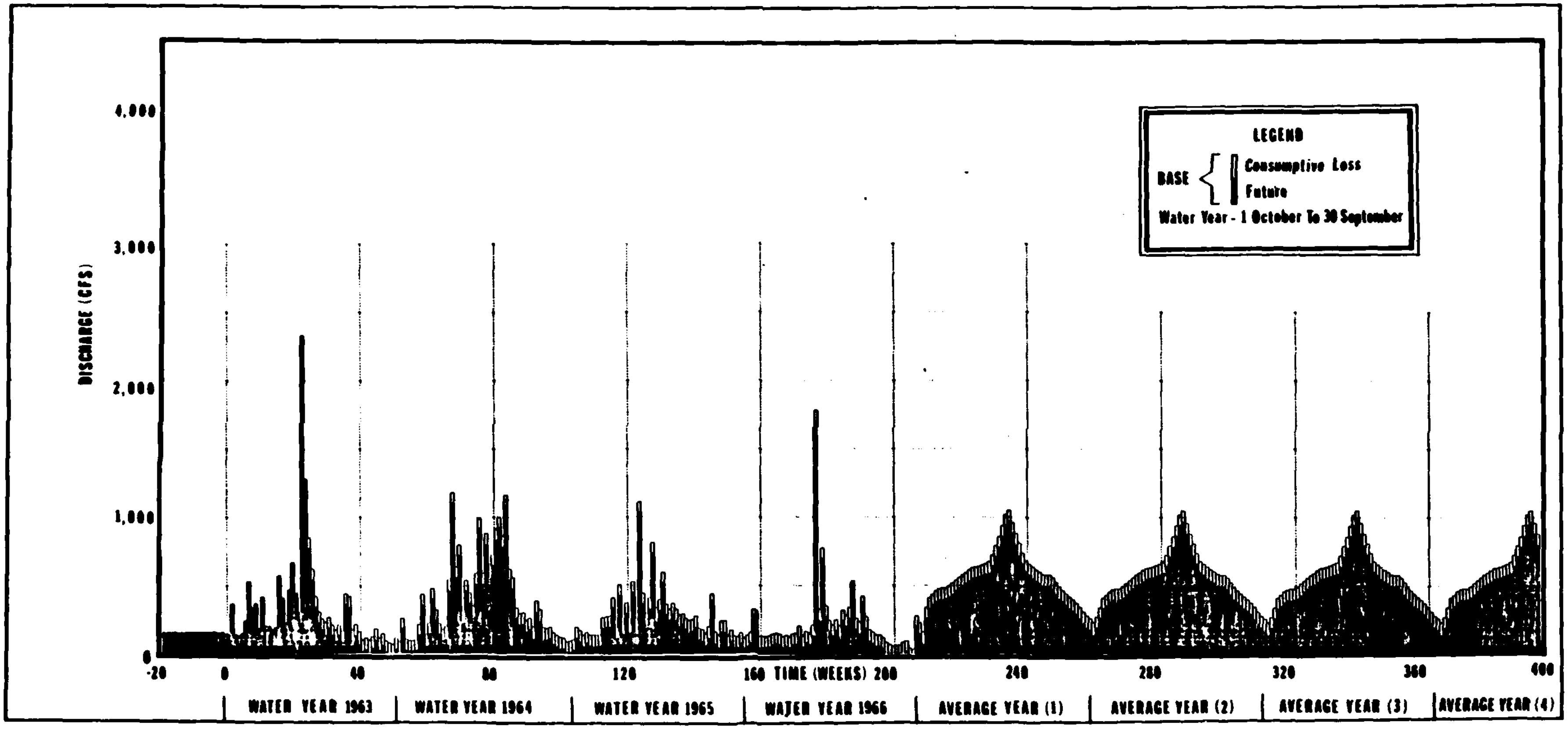


PLATE D-14 INFLOW HYDROGRAPH, INFLOW POINT 14, GUNPOWER RIVER

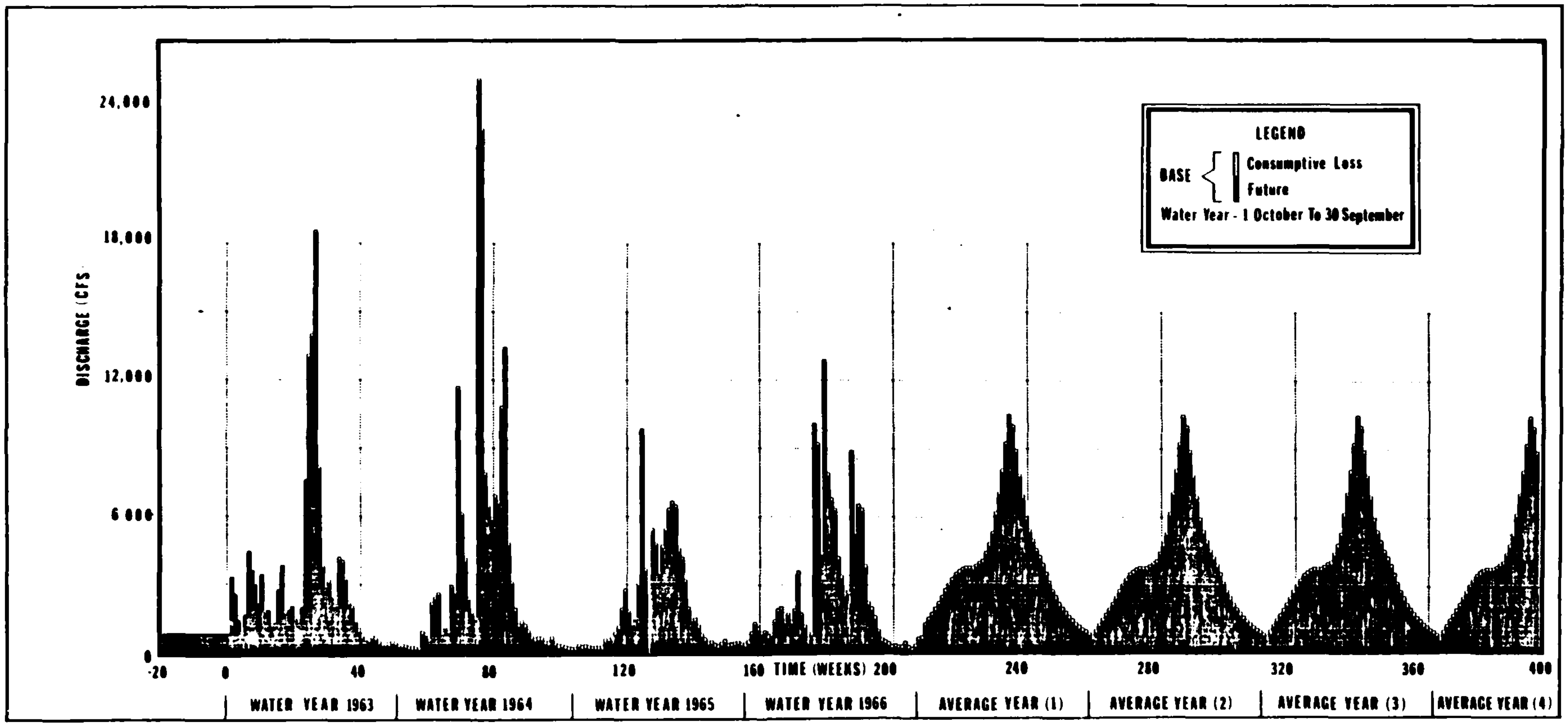


PLATE D-15 INFLOW HYDROGRAPH, INFLOW POINT 15, SUSQUEHANNA RIVER

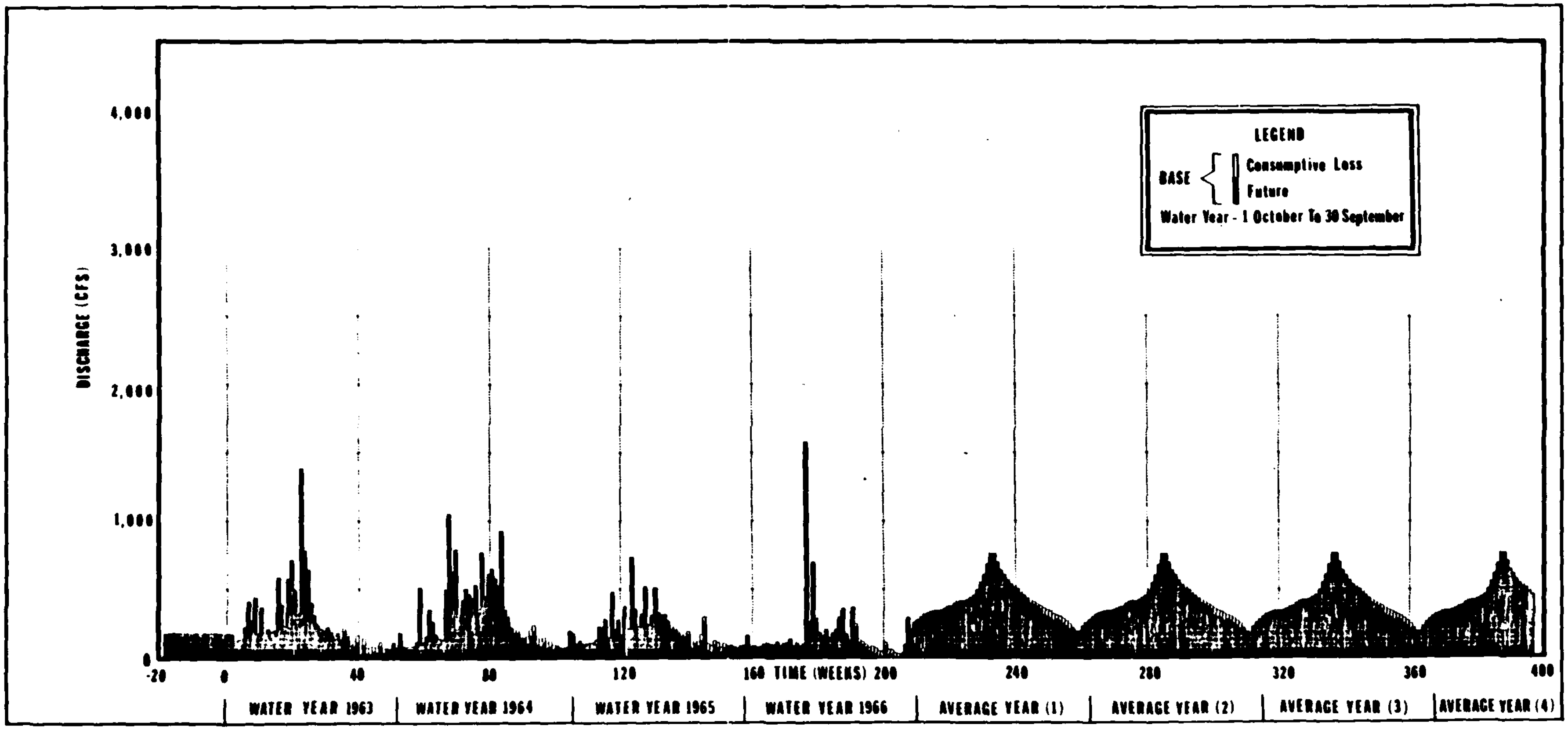


PLATE D-16 INFLOW HYDROGRAPH, INFLOW POINT 16, BOHEMIA RIVER

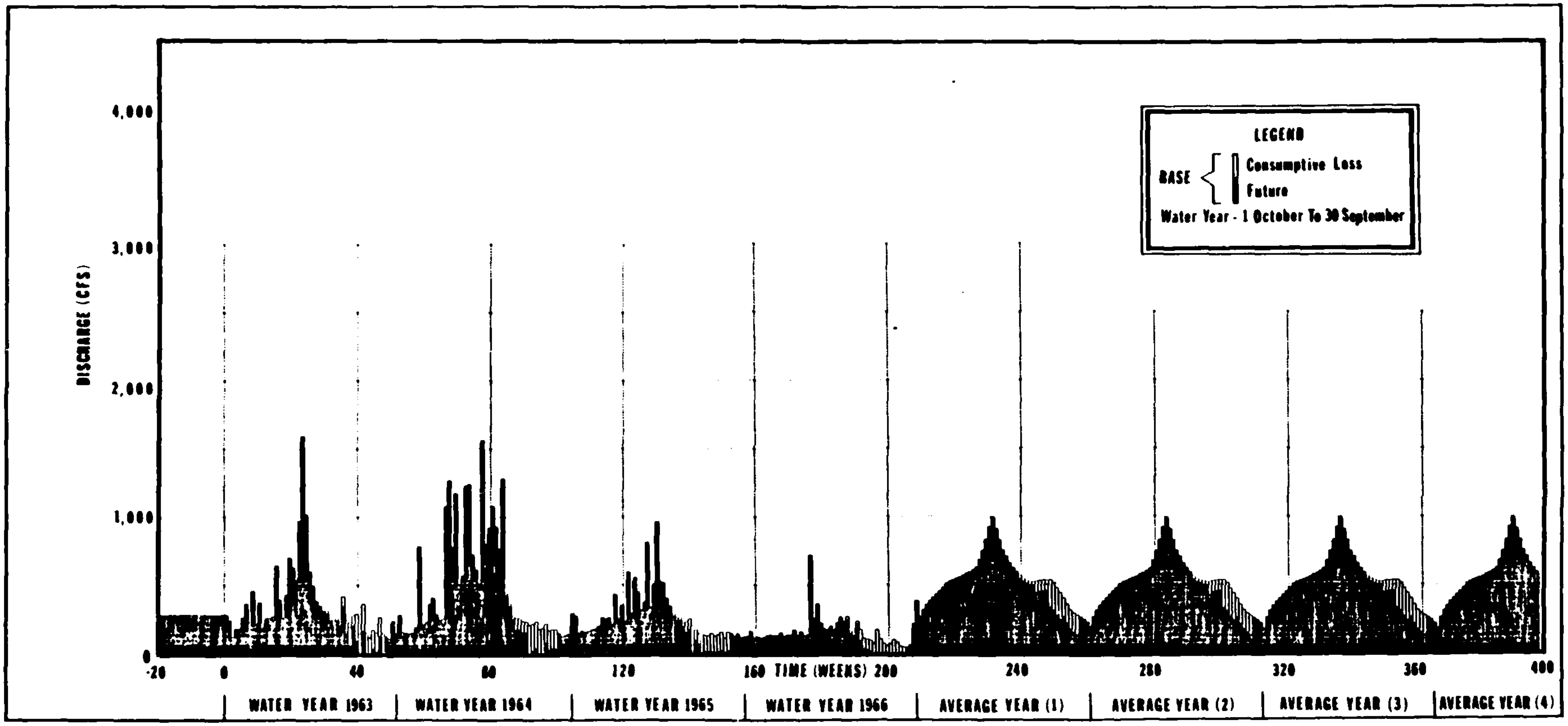


PLATE D-17 INFLOW HYDROGRAPH, INFLOW POINT 17, CHESTER RIVER

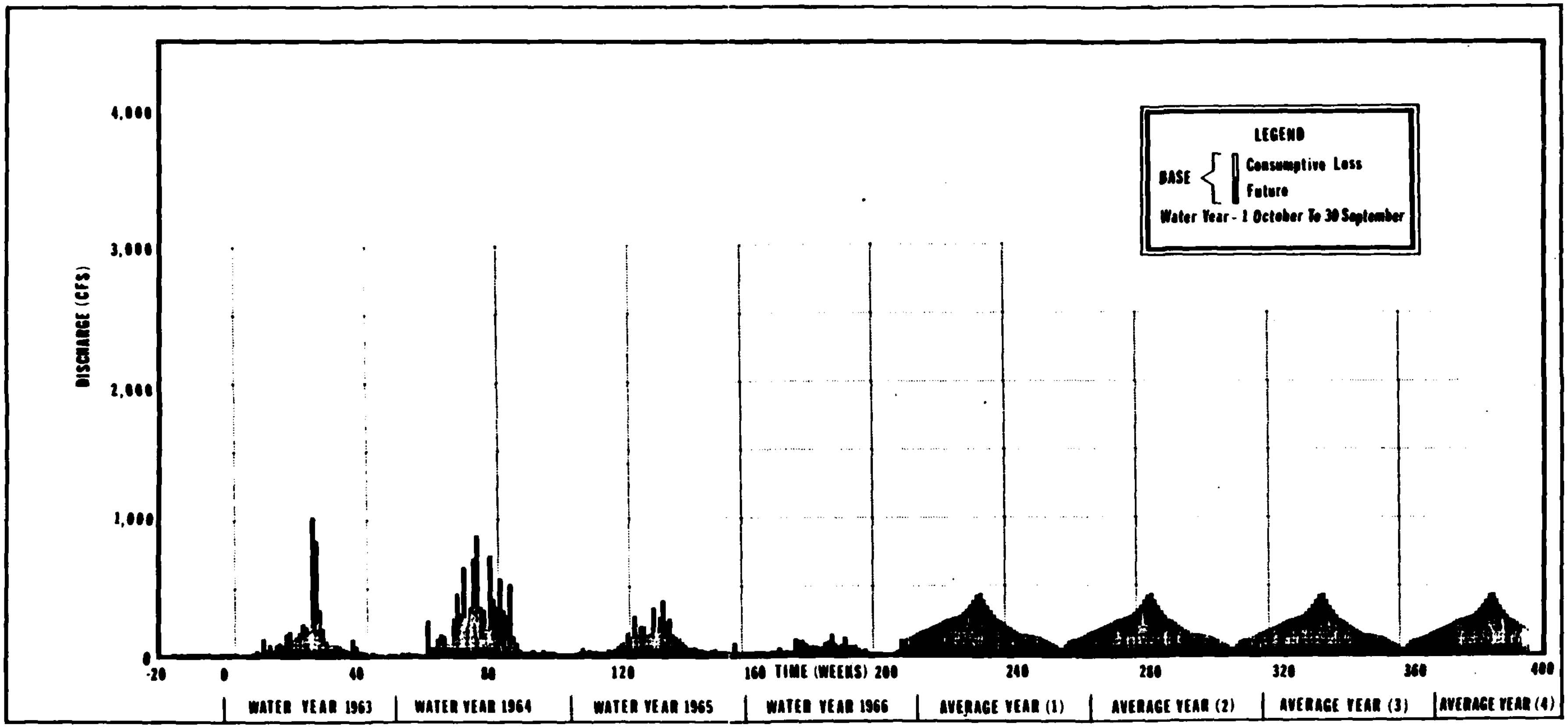


PLATE D-18 INFLOW HYDROGRAPH, INFLOW POINT 18, WYE RIVER

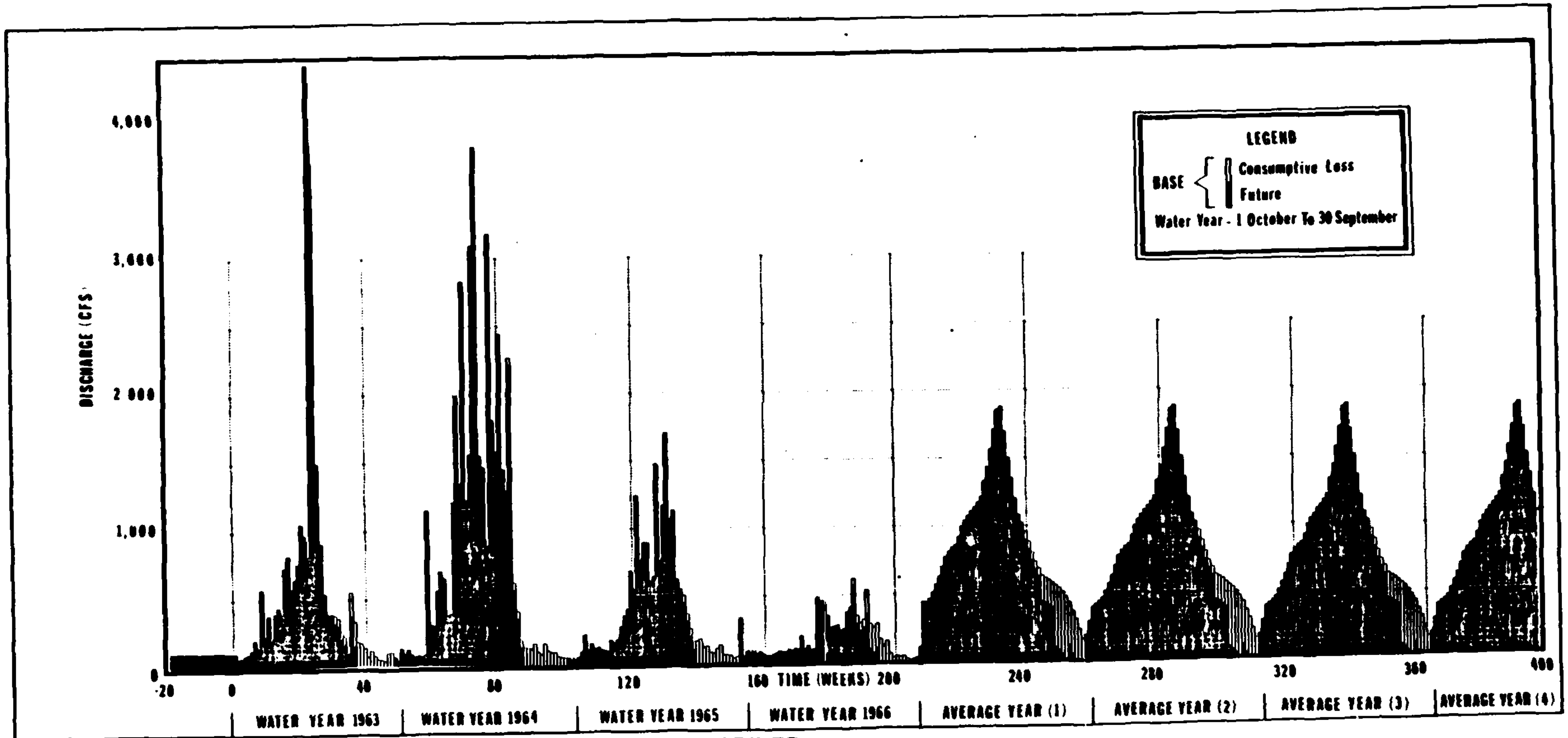


PLATE D-19 INFLOW HYDROGRAPH, INFLOW POINT 19, CHOPTANK RIVER

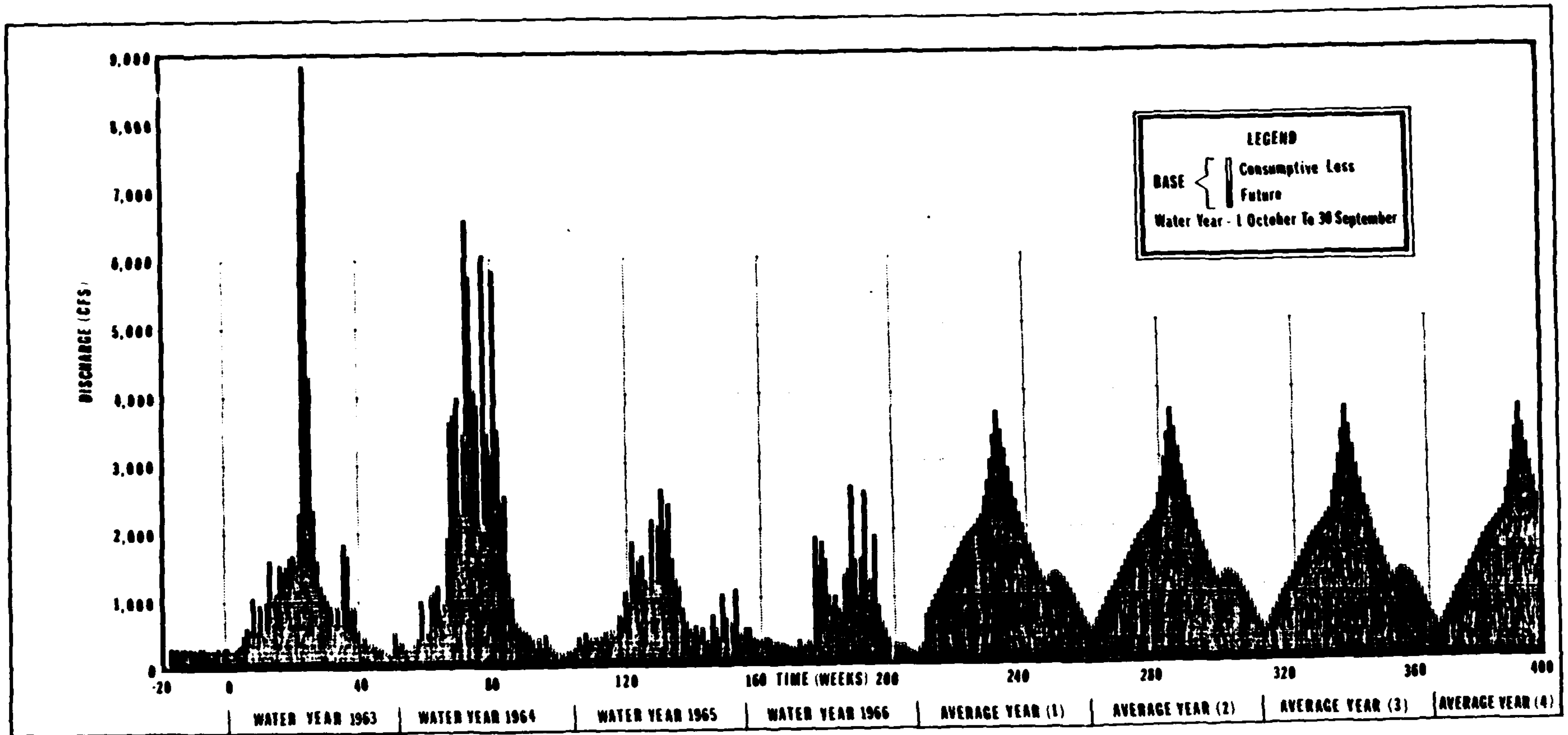


PLATE D- 20 INFLOW HYDROGRAPH, INFLOW POINT 20, NANTICOKE RIVER

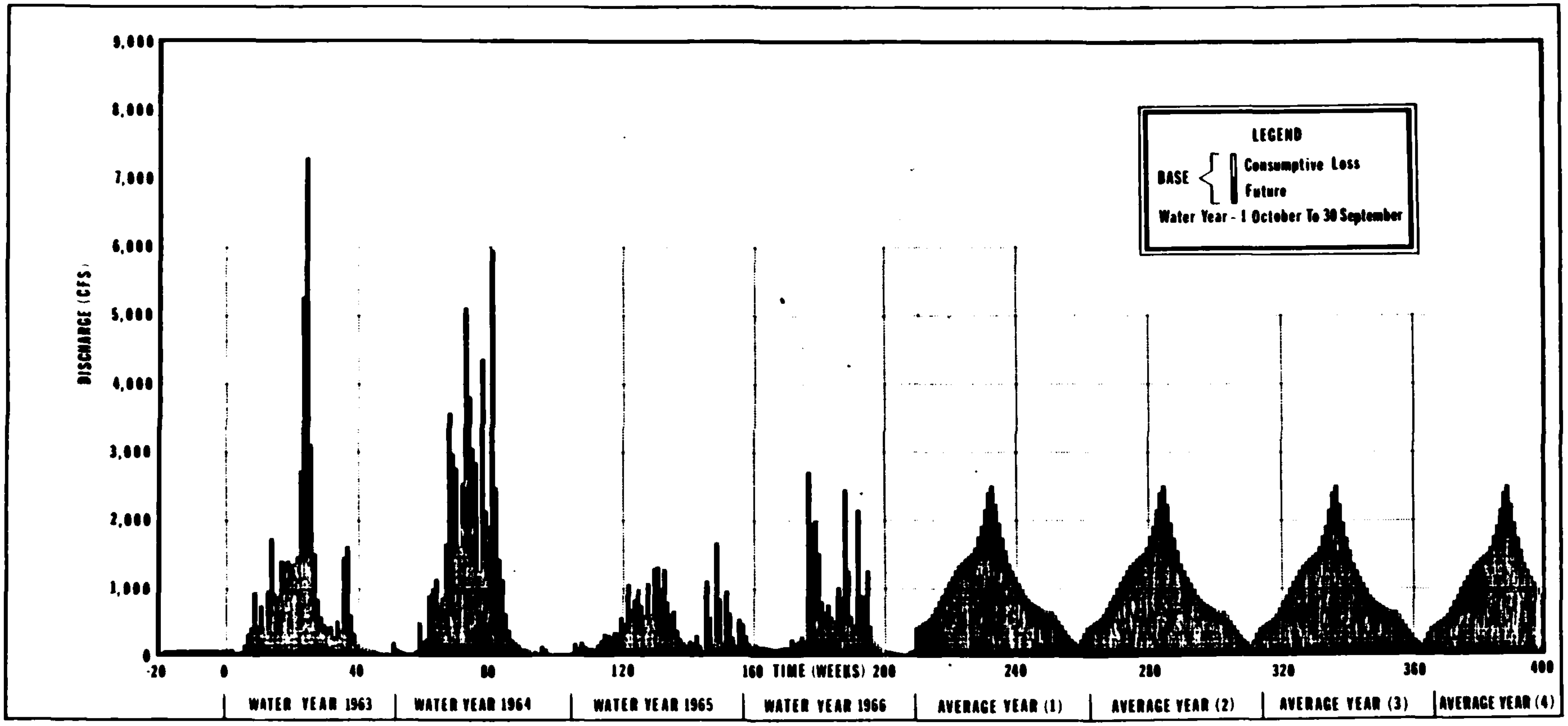


PLATE D-21 INFLOW HYDROGRAPH, INFLOW POINT 21, POCOMOKE RIVER

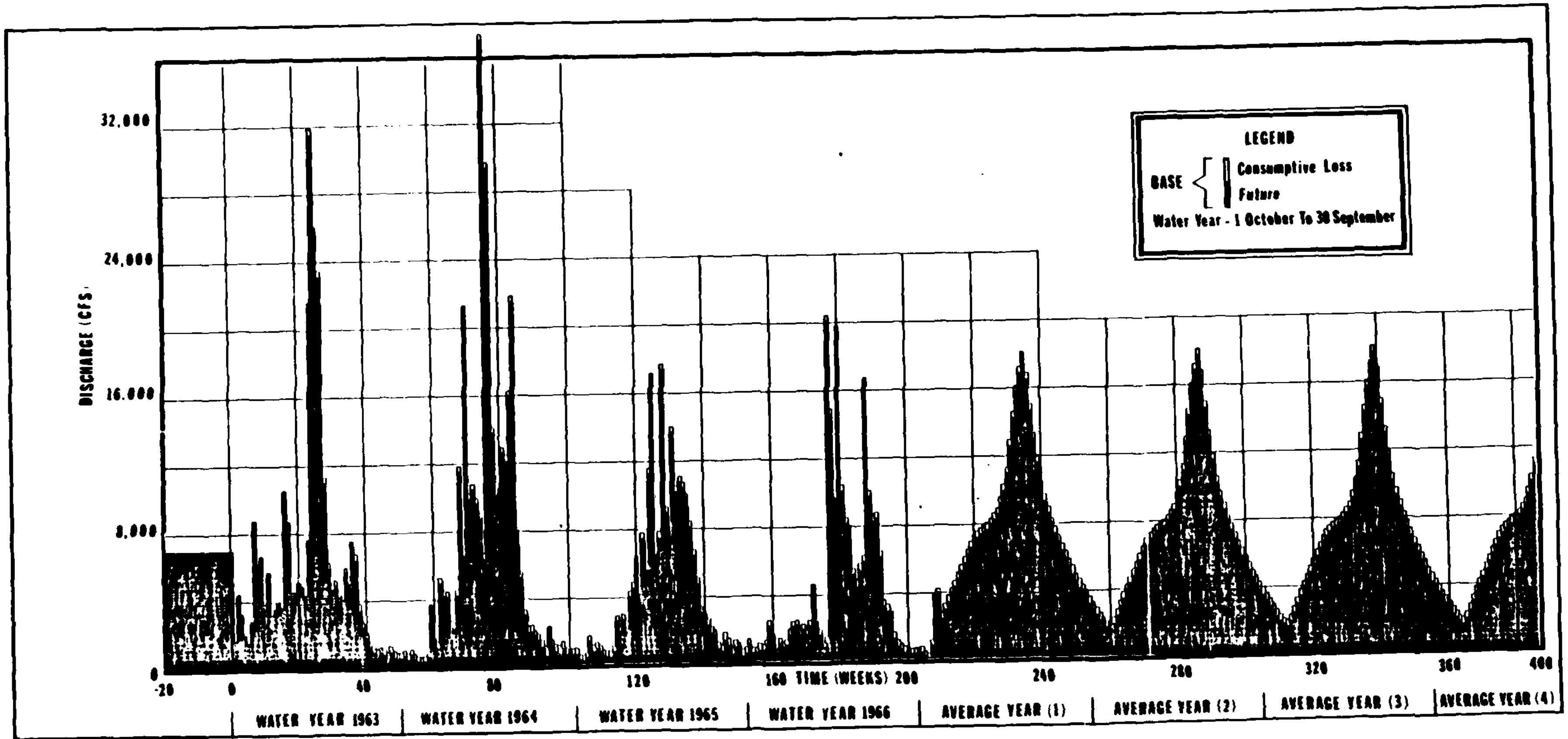


PLATE D-22 INFLOW HYDROGRAPH, TOTAL FRESHWATER INFLOW


CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
SPRING
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST
0.5
10
15
20

PLATE D-23


0.5
1
1
5
5
5
10
5
10
15
15
15
20
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE AVERAGE
SPRING
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-24

CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
SPRING
SURFACE
0.5
1
10
10
10
10
15
15
15
20
20
20
20
20
25

PLATE D-25

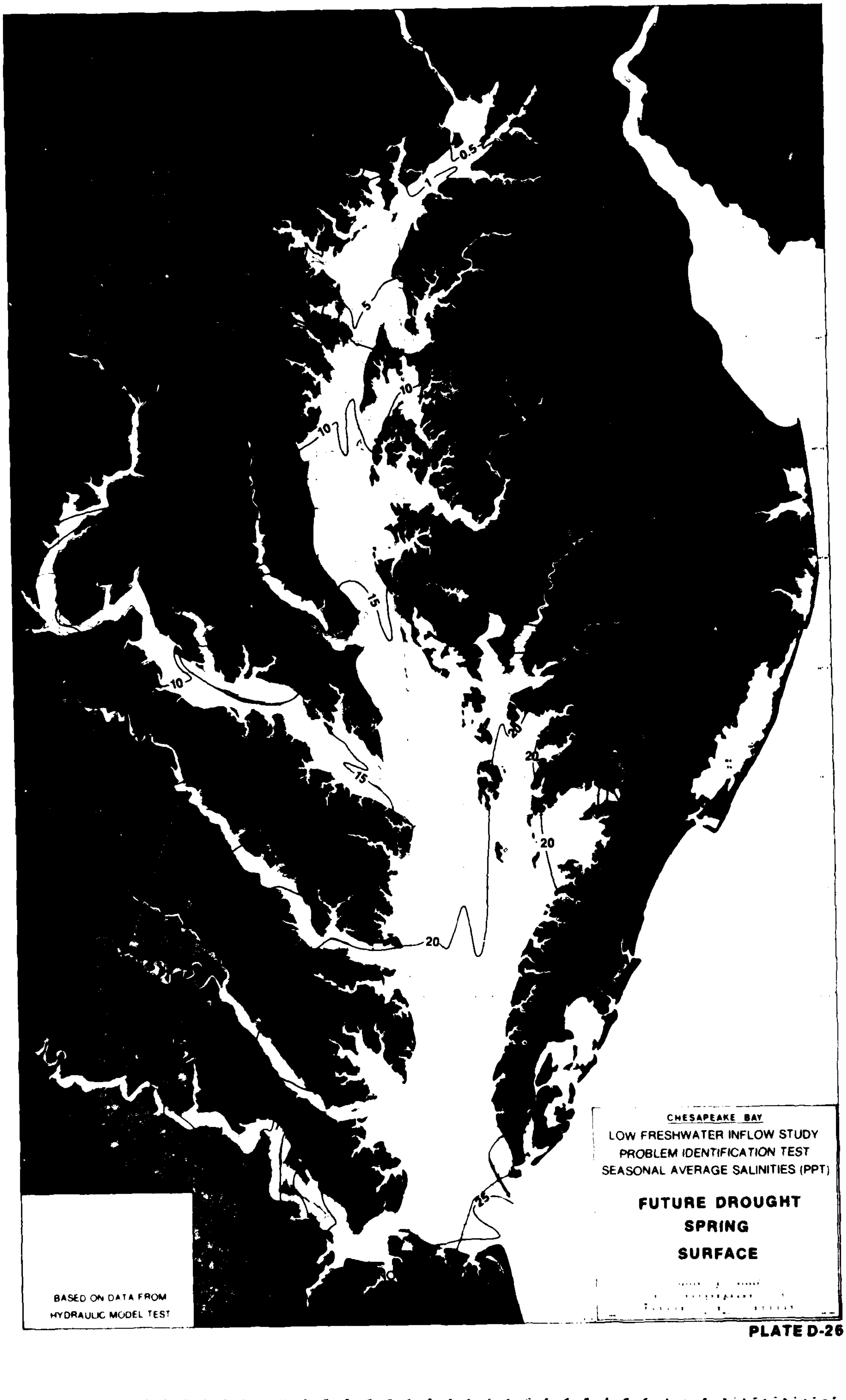

CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE DROUGHT
SPRING
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST
0.5
1
5
10
10
10
15
10
15
20
20
20
20
25

PLATE D-26


0.5
5
10
10
10
10
15
15
20
25
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
SUMMER
SURFACE

PLATE D-27


0.5
1
5
5
10
10
15
15
20
20
25
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE AVERAGE
SUMMER
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-28


10
10
15
15
15
15
20
25
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
SUMMER
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-29


10
15
15
15
15
20
20
20
25
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE DROUGHT
SUMMER
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-30

0.5
10
15
15
15
15
15
20
20
25
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
FALL
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST

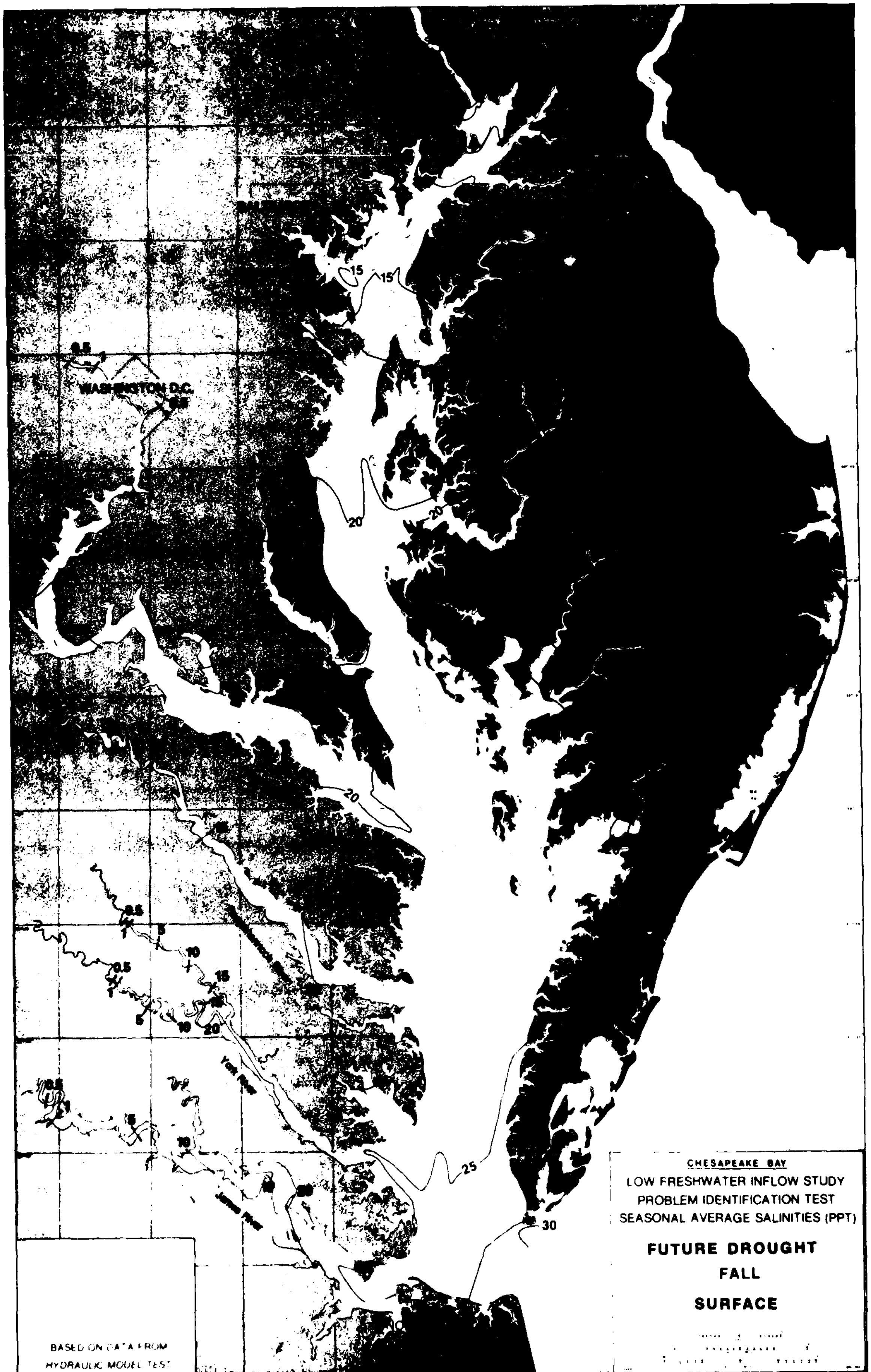
PLATE D-31


CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE AVERAGE
FALL
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST
0.5
5
10
10
10
15
15
20
20
20
25

PLATE D-32


CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
FALL
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST
15
20
25

PLATE D-33



CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)

FUTURE DROUGHT
FALL
SURFACE

PLATE D-34


CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
WINTER
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-35

CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)

FUTURE AVERAGE
WINTER
SURFACE

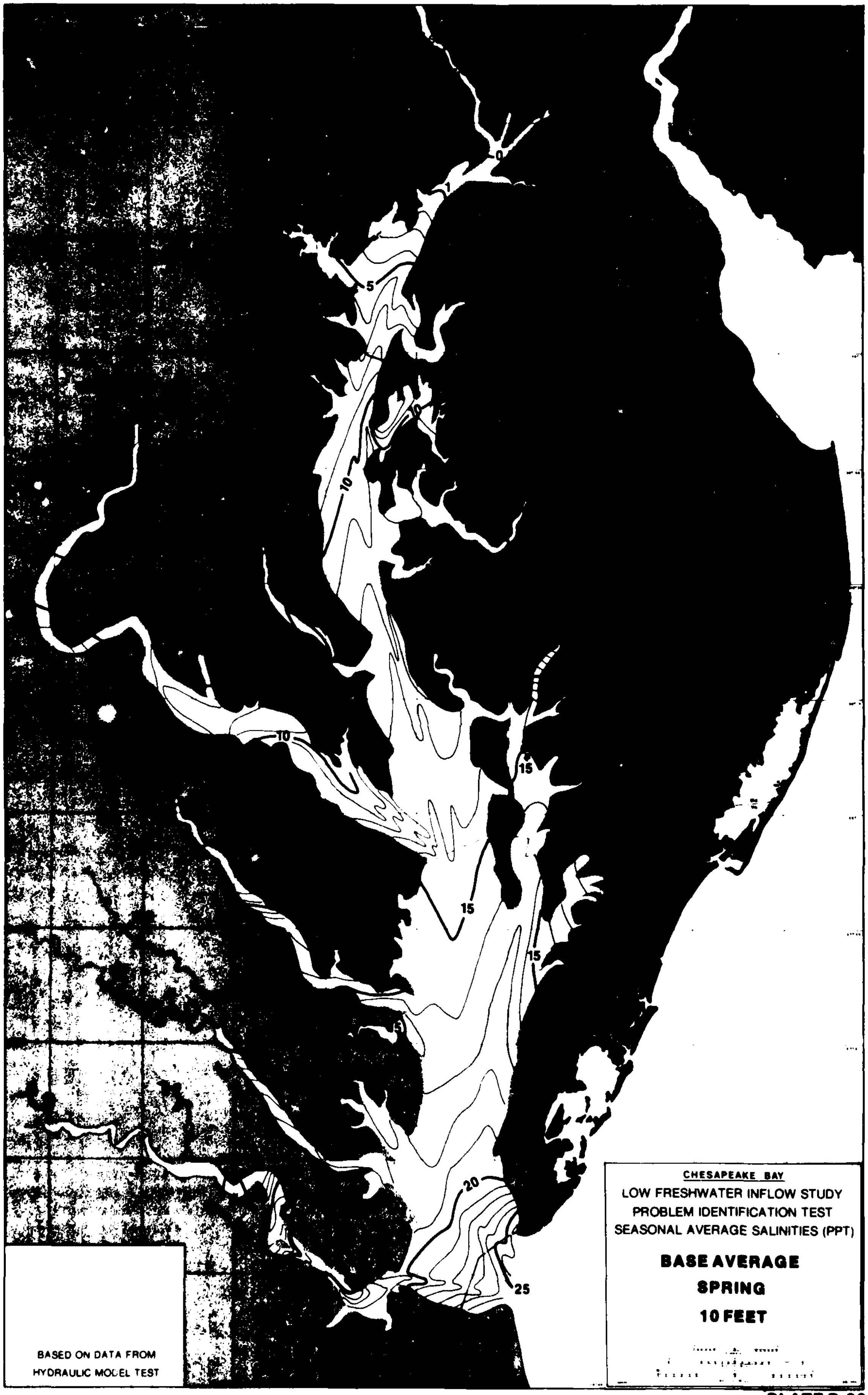
PLATE D-36

PLATE D-37

341

10
15
20
20
25
25
30
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE DROUGHT
WINTER
SURFACE
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-38



0
1
5
10
10
10
15
15
15
15
20
25
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
SPRING
10 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-39


5
10
10
15
15
20
20
25
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE AVERAGE
SPRING
10 FEET

PLATE D-40

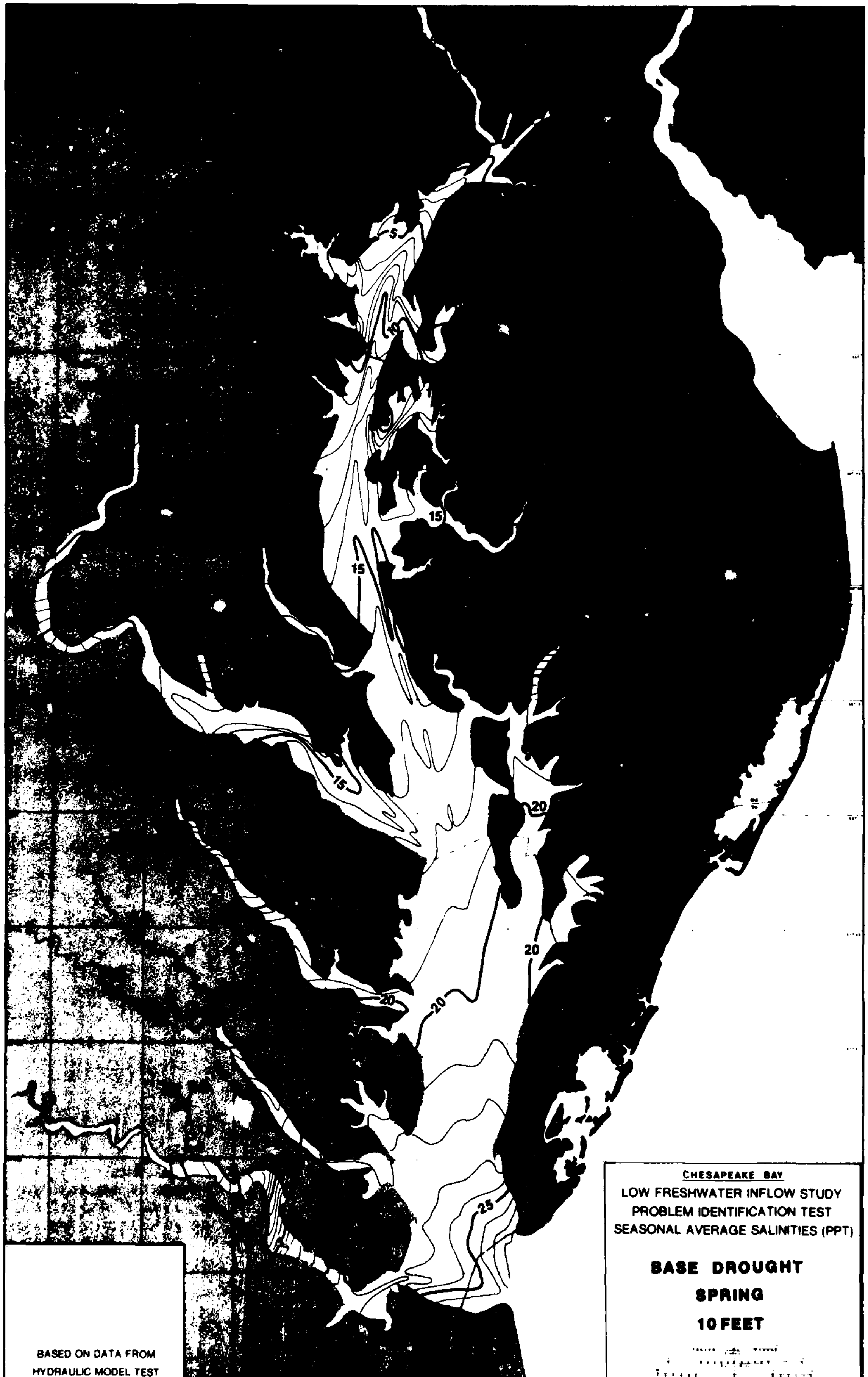
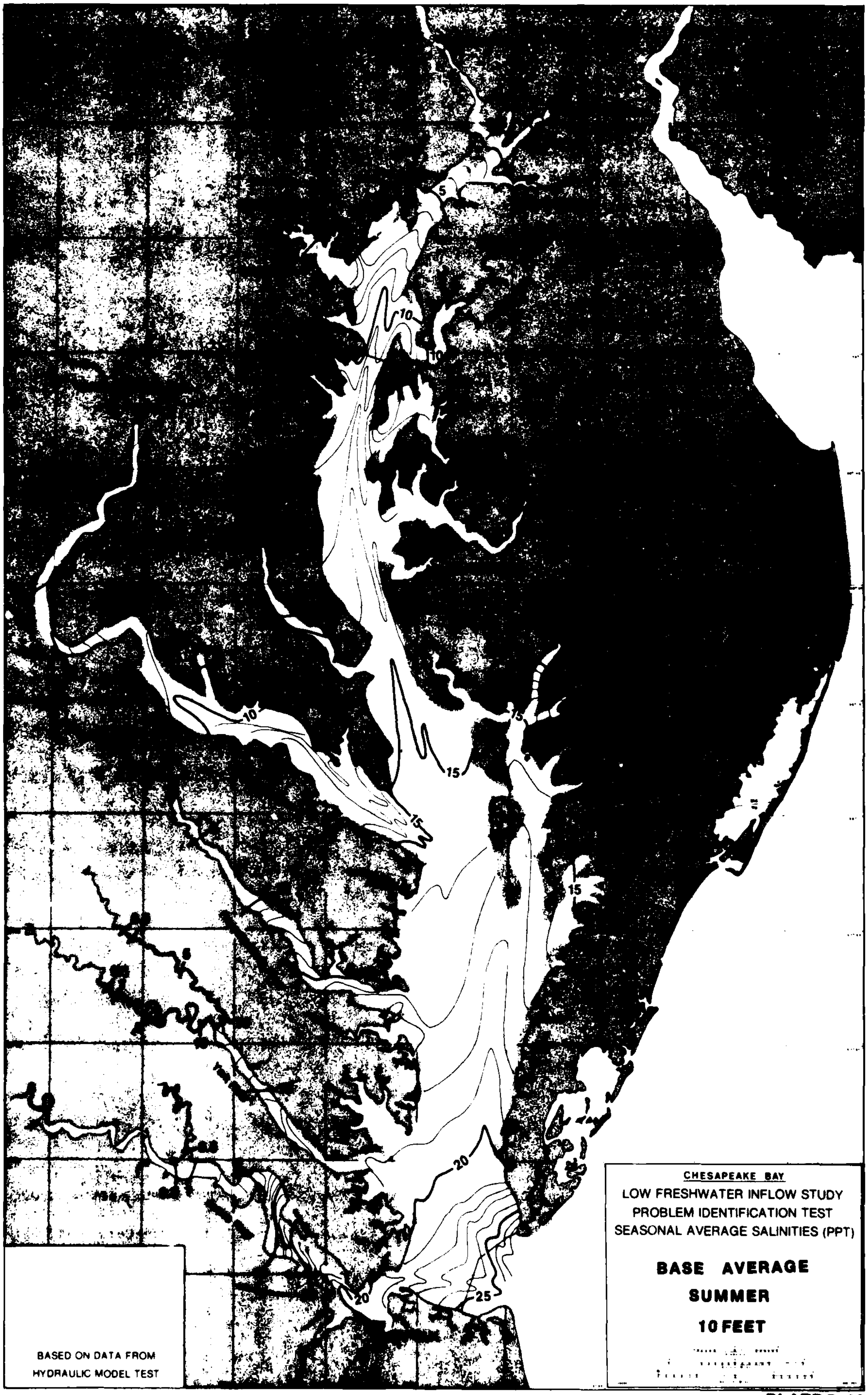

5
10
15
15
15
15
20
20
20
20
25
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
SPRING
10 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-41


CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE DROUGHT
SPRING
10 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST
NORFOLK

PLATE-42

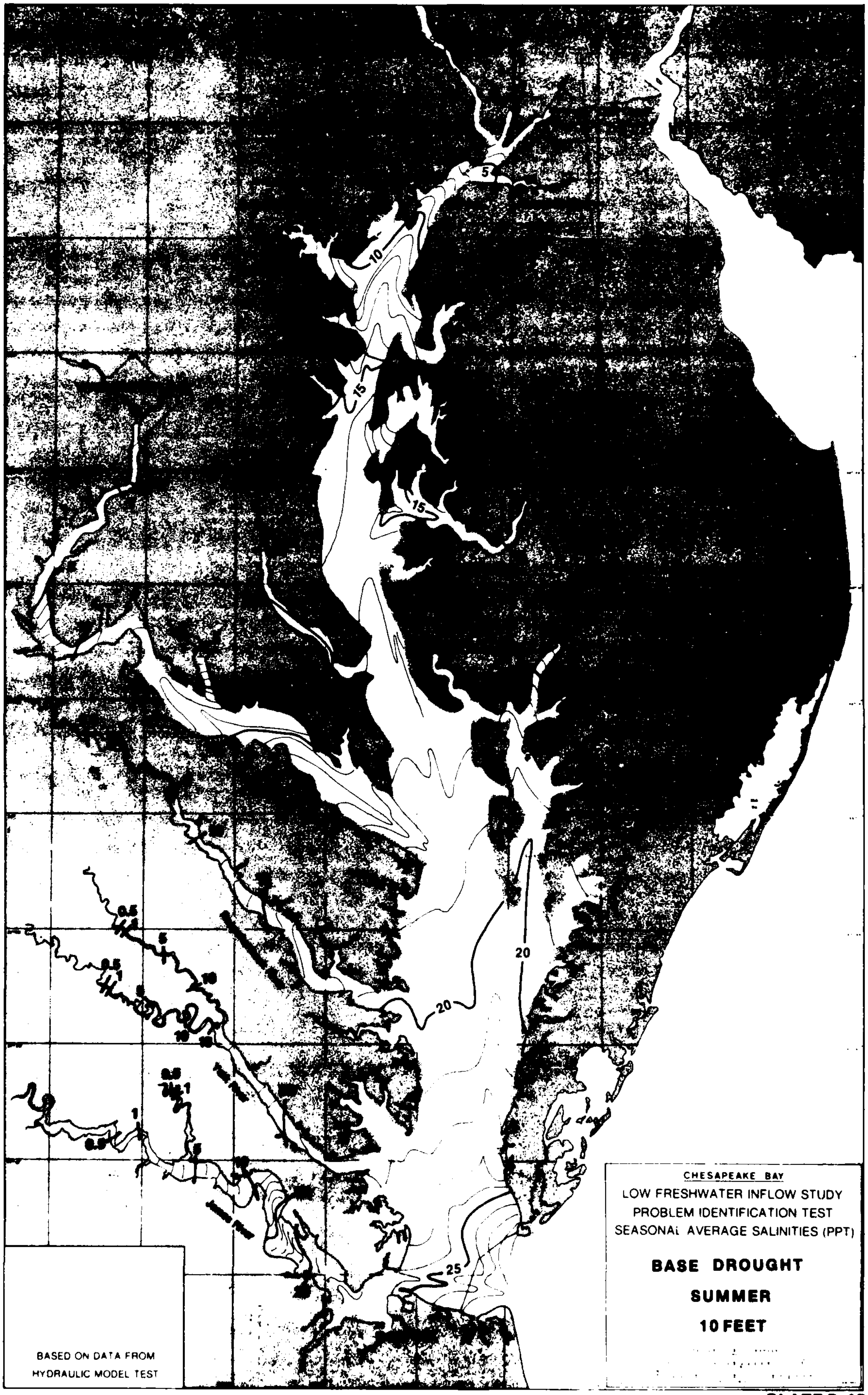


5
10
10
10
15
15
15
15
20
20
25
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
SUMMER
10 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-43


Susquehanna River
C&D Canal
BALTIMORE
Sassafras River
Patapsco River
Chester River
WASHINGTON D.C.
EASTON
Choptank River
CAMBRIDGE
Patuxent River
Potomac River
Rappahannock River
York River
James River
NORFOLK
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE AVERAGE
SUMMER
10 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-44



5
10
15
15
20
20
25
0.5
1
5
10
1
0.5
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
SUMMER
10 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-45


WASHINGTON D.C.
15
15
15
20
20
20
0.5
1
5
10
0.5
1
5
10
15
20
20
0.5
1
0.5
1
5
5
15
15
20
25
30
NORFOLK
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE DROUGHT
SUMMER
10 FEET

PLATE D-46


10
15
15
15
20
25
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
FALL
10 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-47

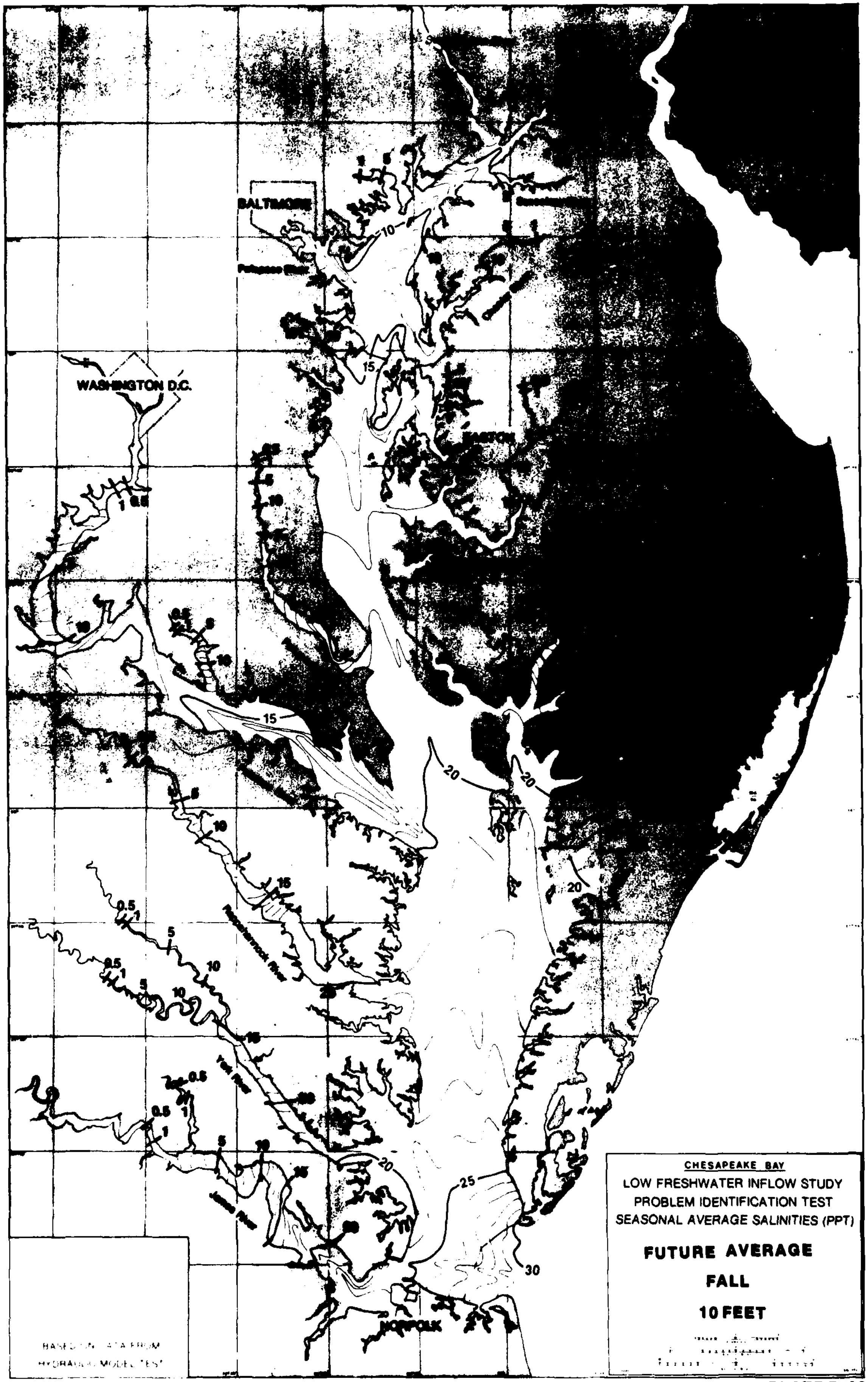

BALTIMORE
WASHINGTON D.C.
NORFOLK
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE AVERAGE
FALL
10 FEET

PLATE D-48


15
20
20
20
25
30
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
FALL
10 FEET

PLATE D-49

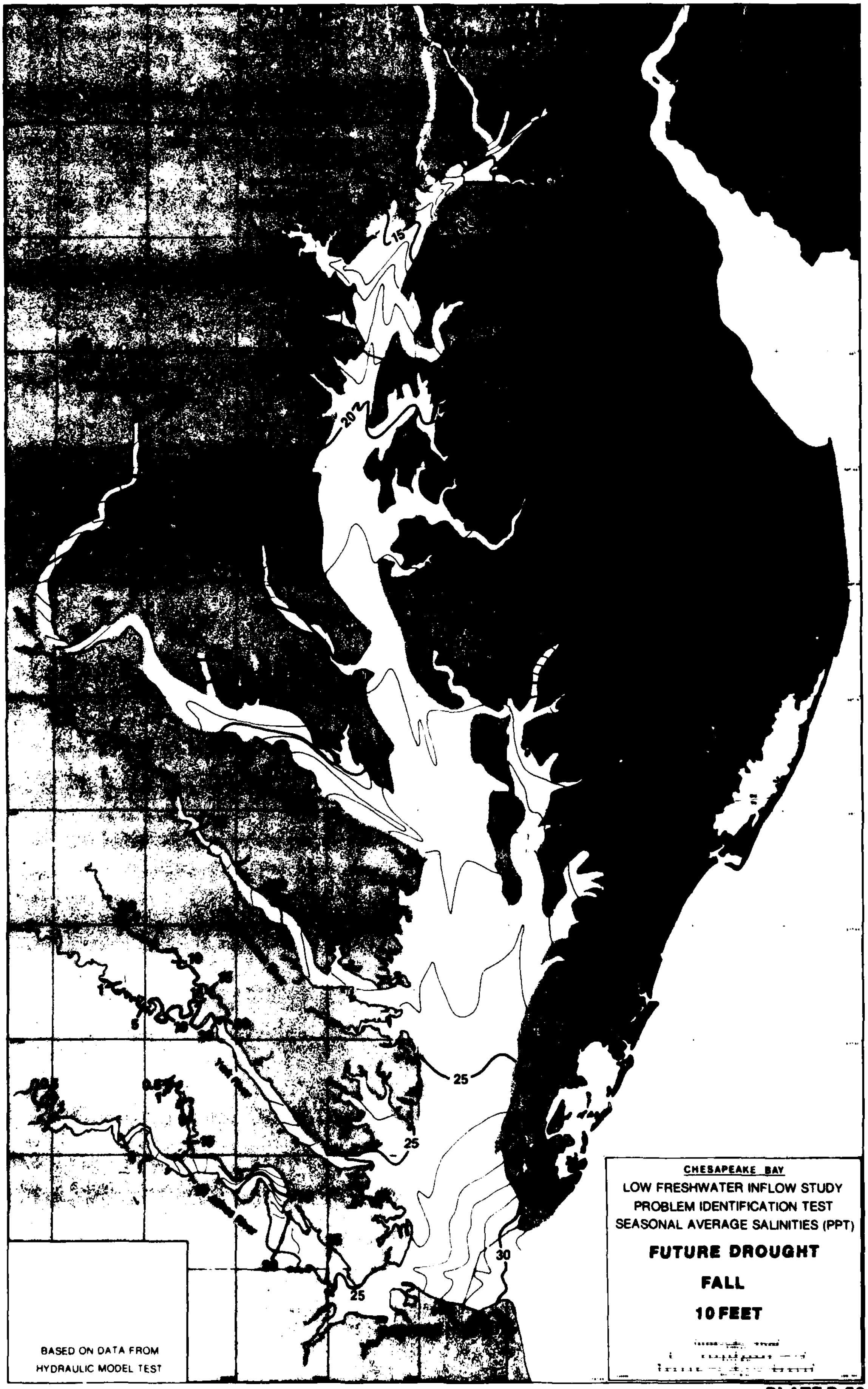
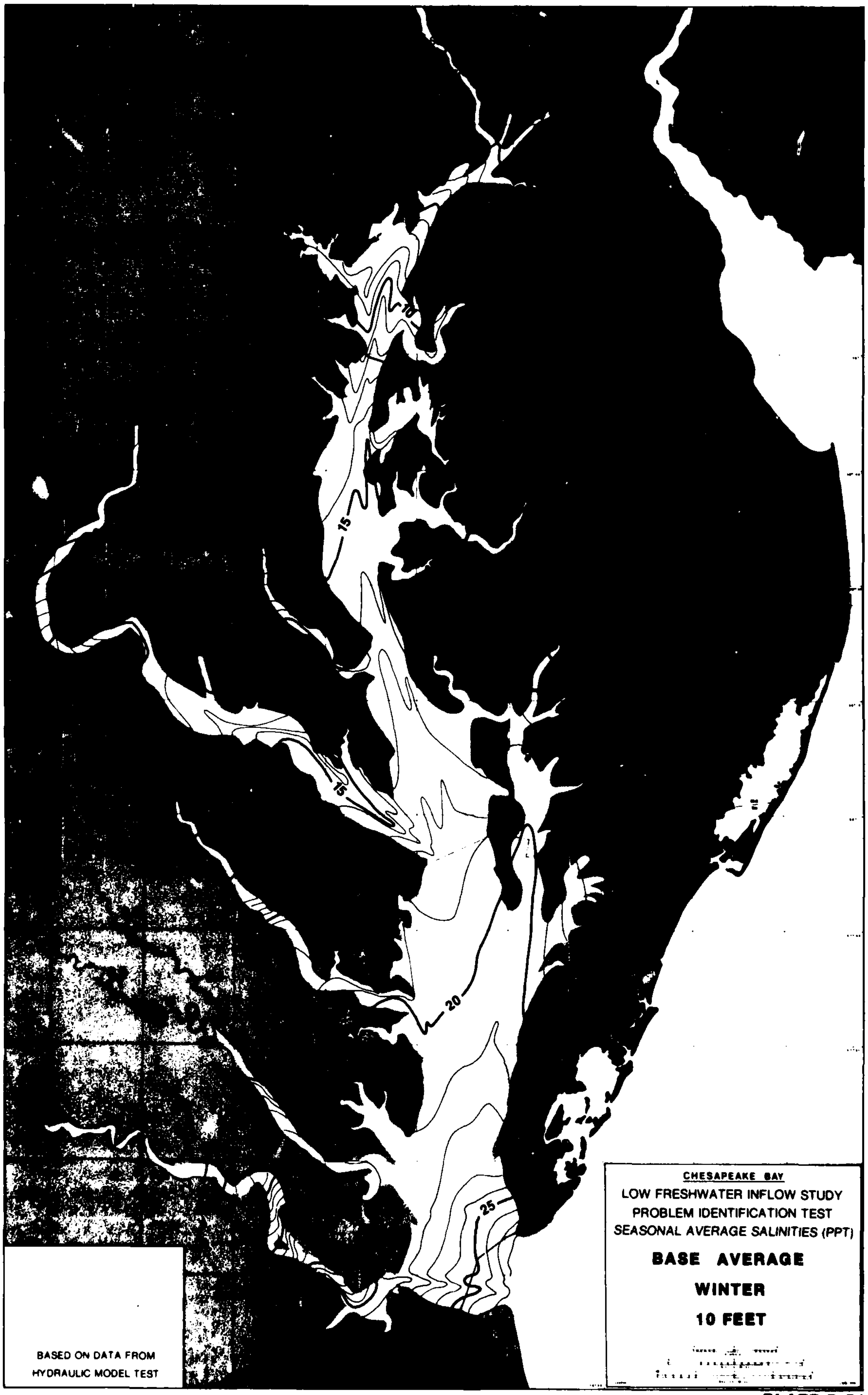

15
20
25
25
25
30
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE DROUGHT
FALL
10 FEET

PLATE D-50



CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)

BASE AVERAGE

WINTER

10 FEET

PLATE D-51


Susquehanna River
10
15
20
20
20
25
30
NORFOLK
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE AVERAGE
WINTER
10 FEET

PLATE D-52


15
20
20
20
25
30 0
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
WINTER
10 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-53


15
20
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20
25
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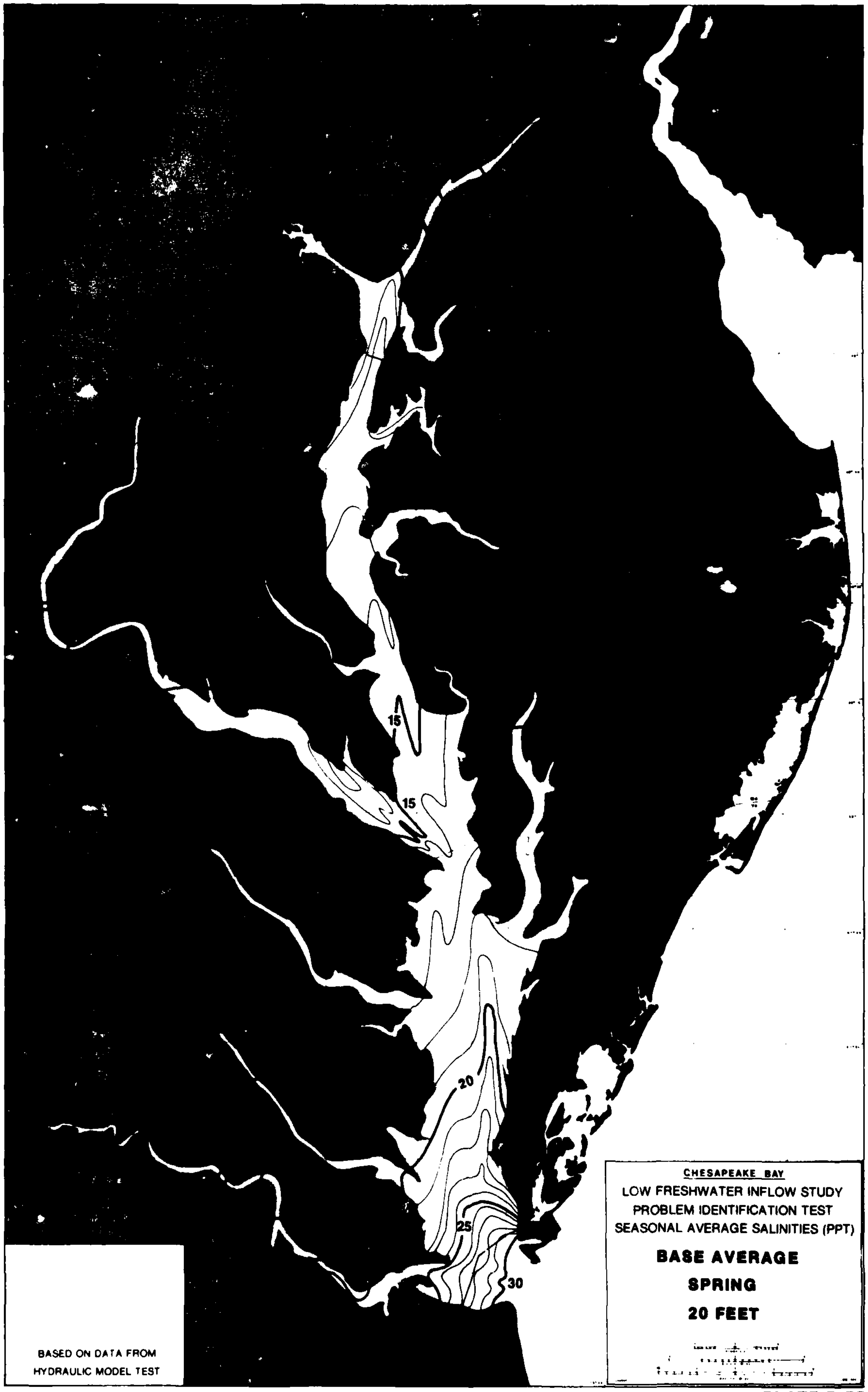
NORFOLK
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE DROUGHT
WINTER
10 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-54


15
15
20
25
30
BASED ON DATA FROM
HYDRAULIC MODEL TEST
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
SPRING
20 FEET

CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)

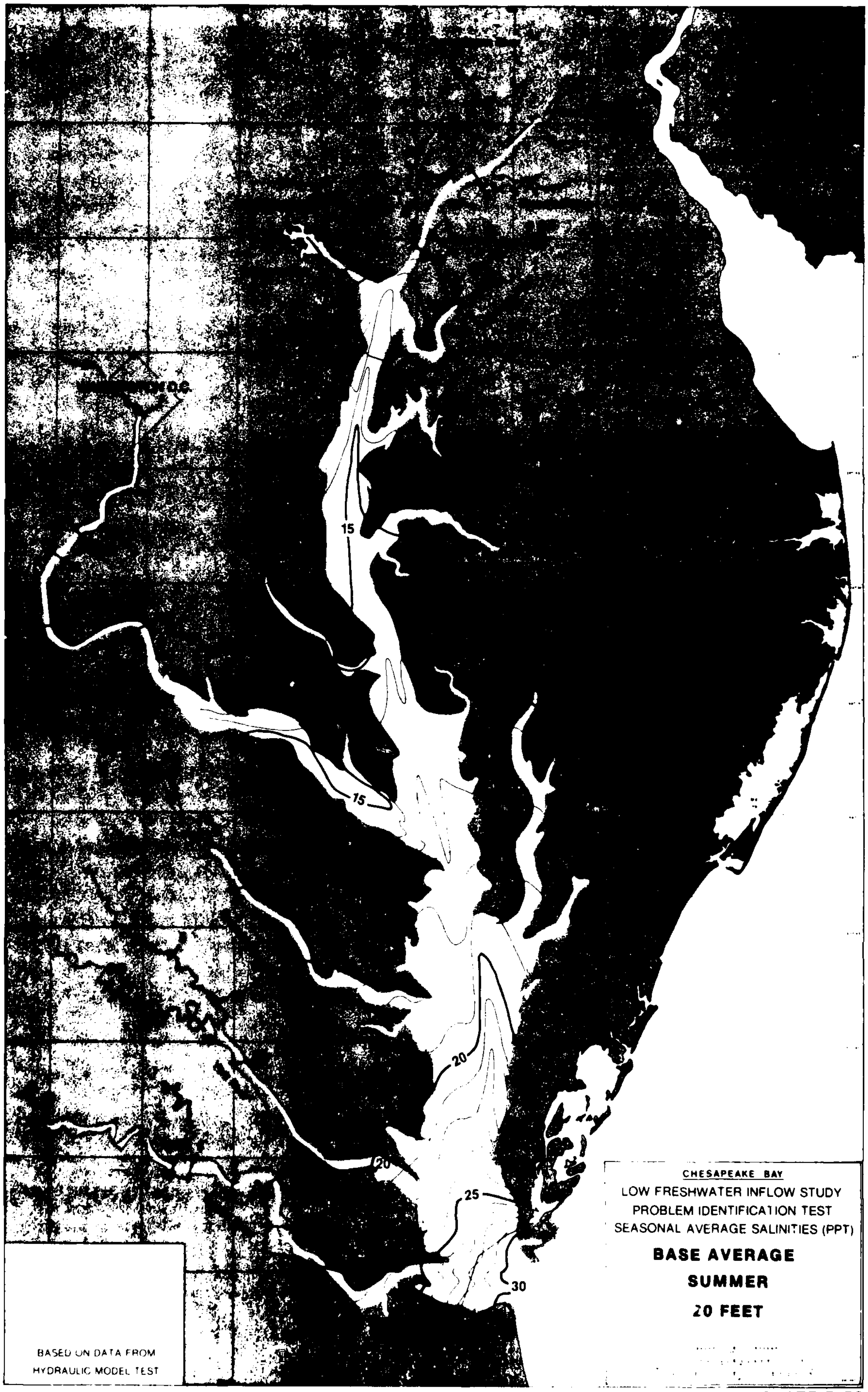
FUTURE AVERAGE
SPRING
20 FEET

PLATE D-56


15
20
20
25
30
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
SPRING
20 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST


20
25
30
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE DROUGHT
SPRING
20 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-58


15
15
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25
30
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
SUMMER
20 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-59

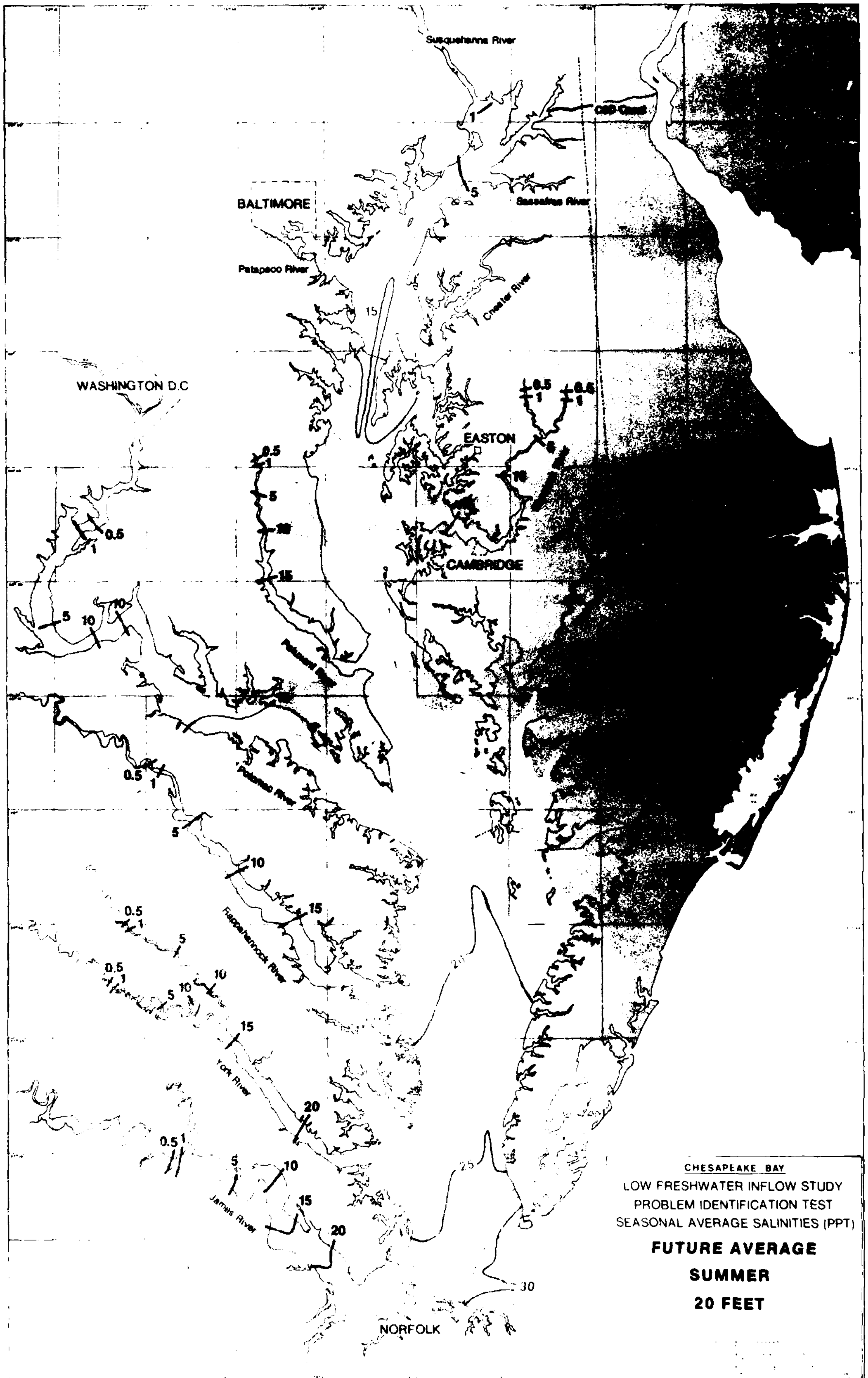
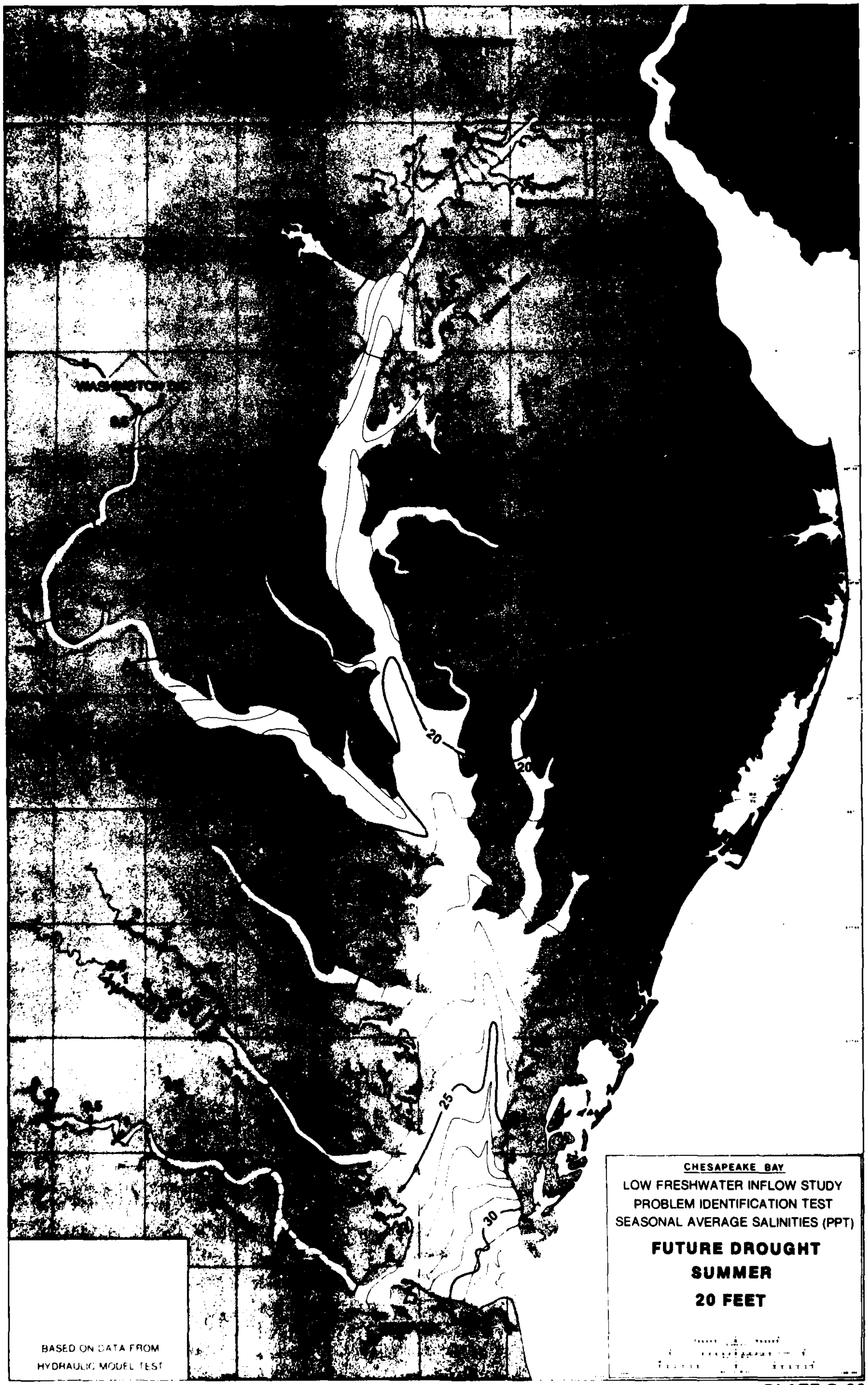

Susquehanna River
C&D Canal
BALTIMORE
Sassafras River
Patapsco River
Chester River
WASHINGTON D.C
EASTON
CAMBRIDGE
Patuxent River
Potomac River
Rappahannock River
York River
James River
NORFOLK
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE AVERAGE
SUMMER
20 FEET

PLATE D-60


15
20
25
30
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
SUMMER
20 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

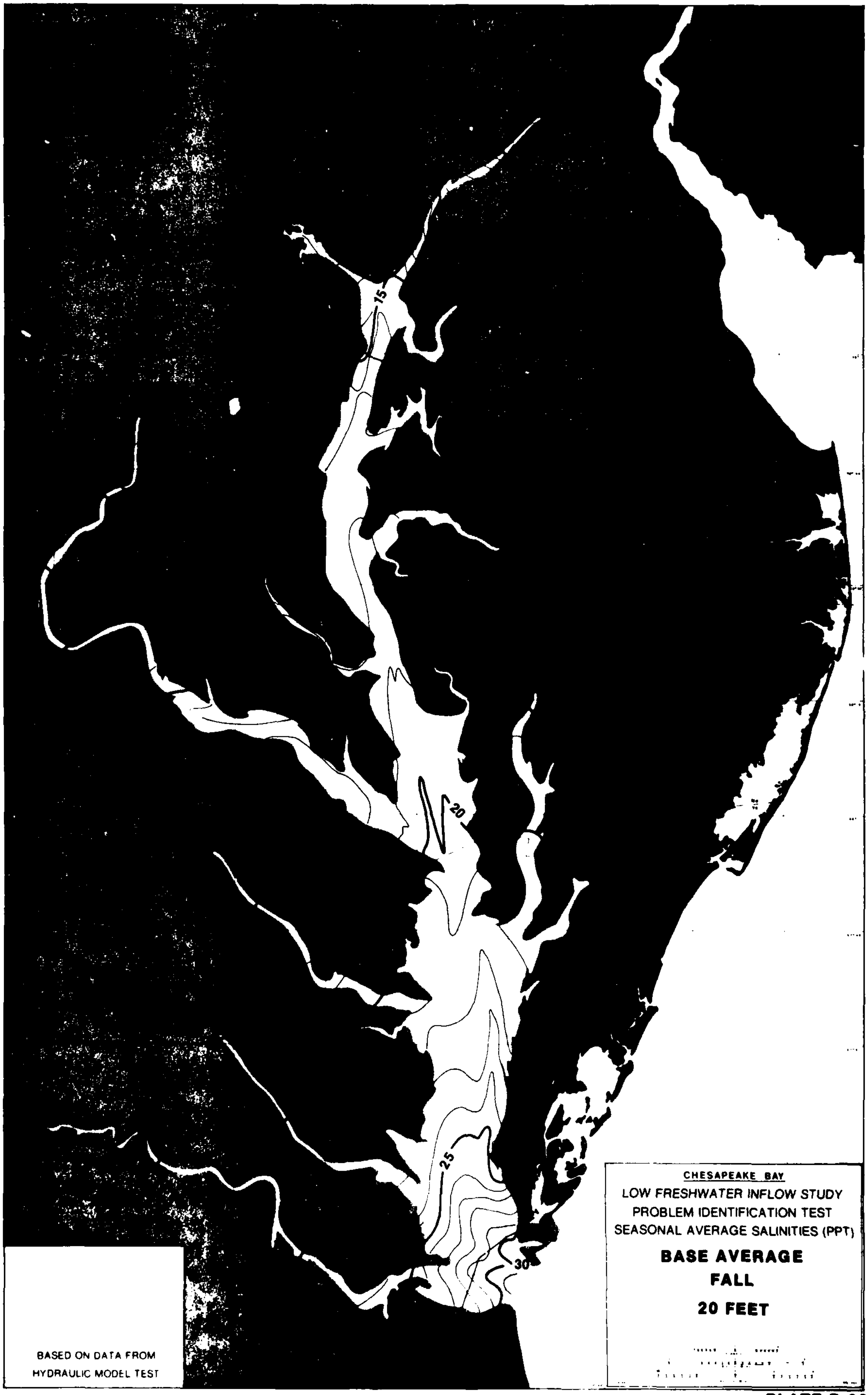
PLATE D-61



CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)

FUTURE DROUGHT
SUMMER
20 FEET

PLATE D-62


15
20
25
30
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
FALL
20 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

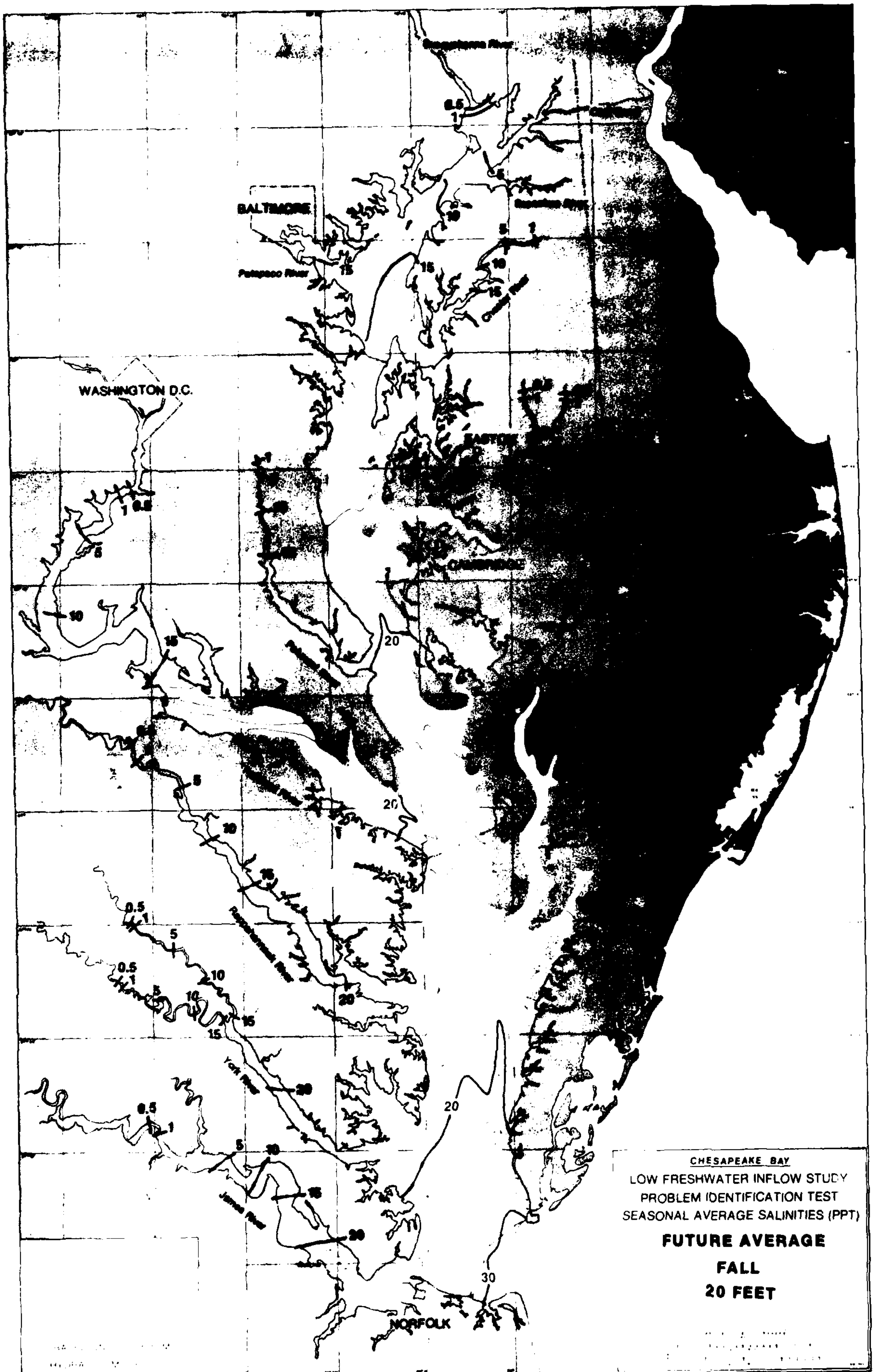
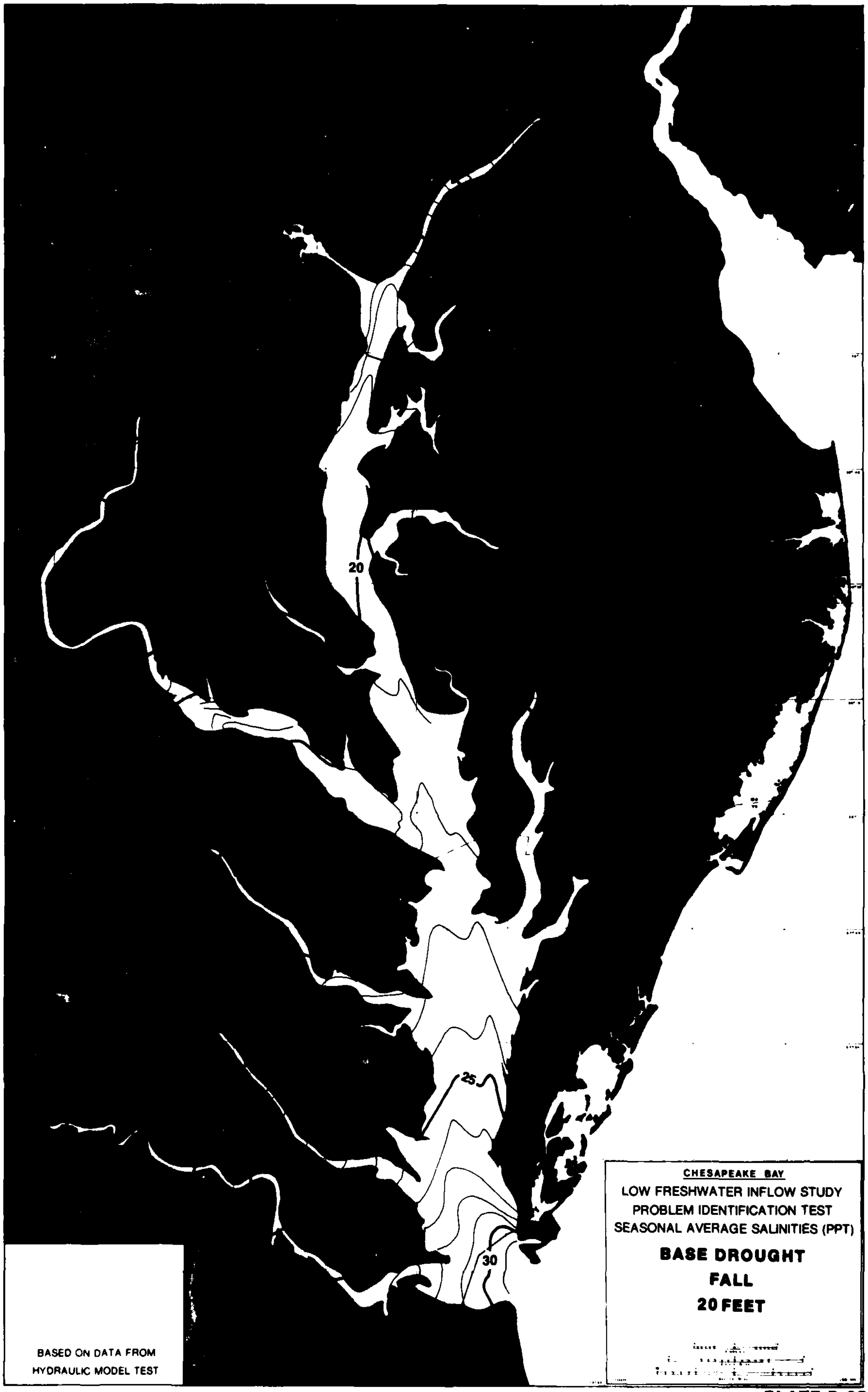

BALTIMORE
Patapsco River
WASHINGTON D.C.
NORFOLK
York River
James River
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE AVERAGE
FALL
20 FEET

PLATE D-64


20
25
30
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
FALL
20 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

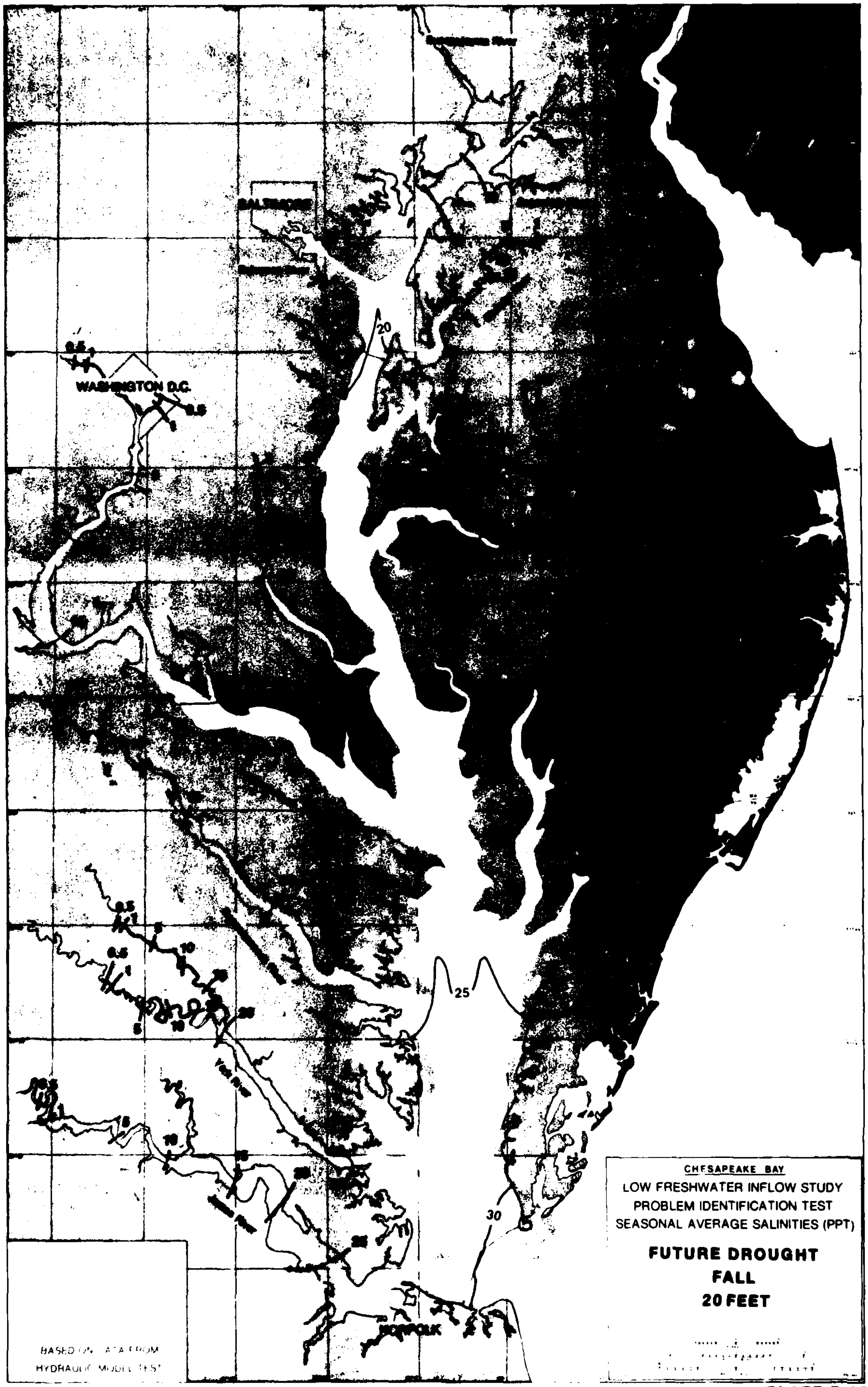

WASHINGTON D.C.
20
25
30
NORFOLK
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
FUTURE DROUGHT
FALL
20 FEET

PLATE D-66

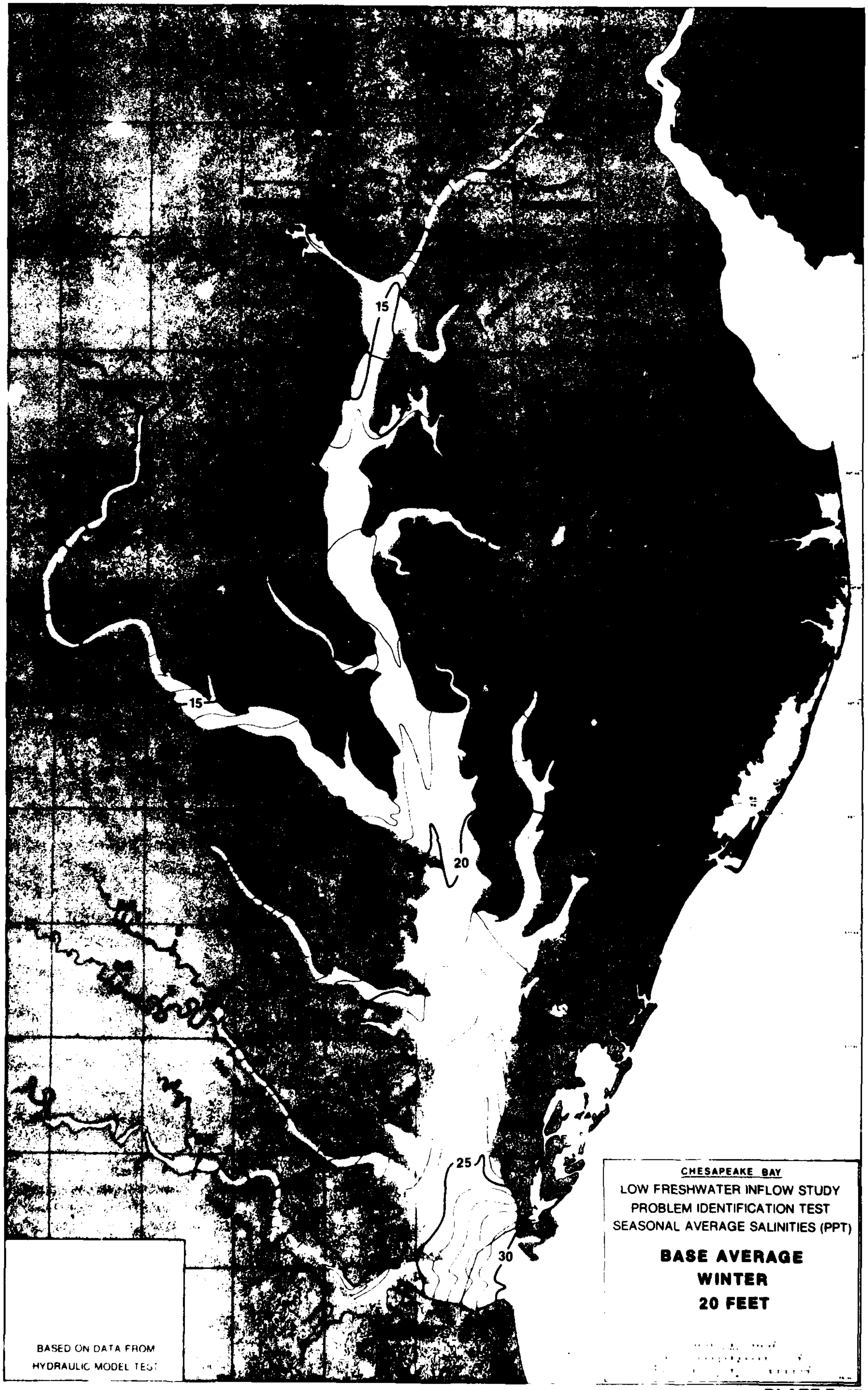
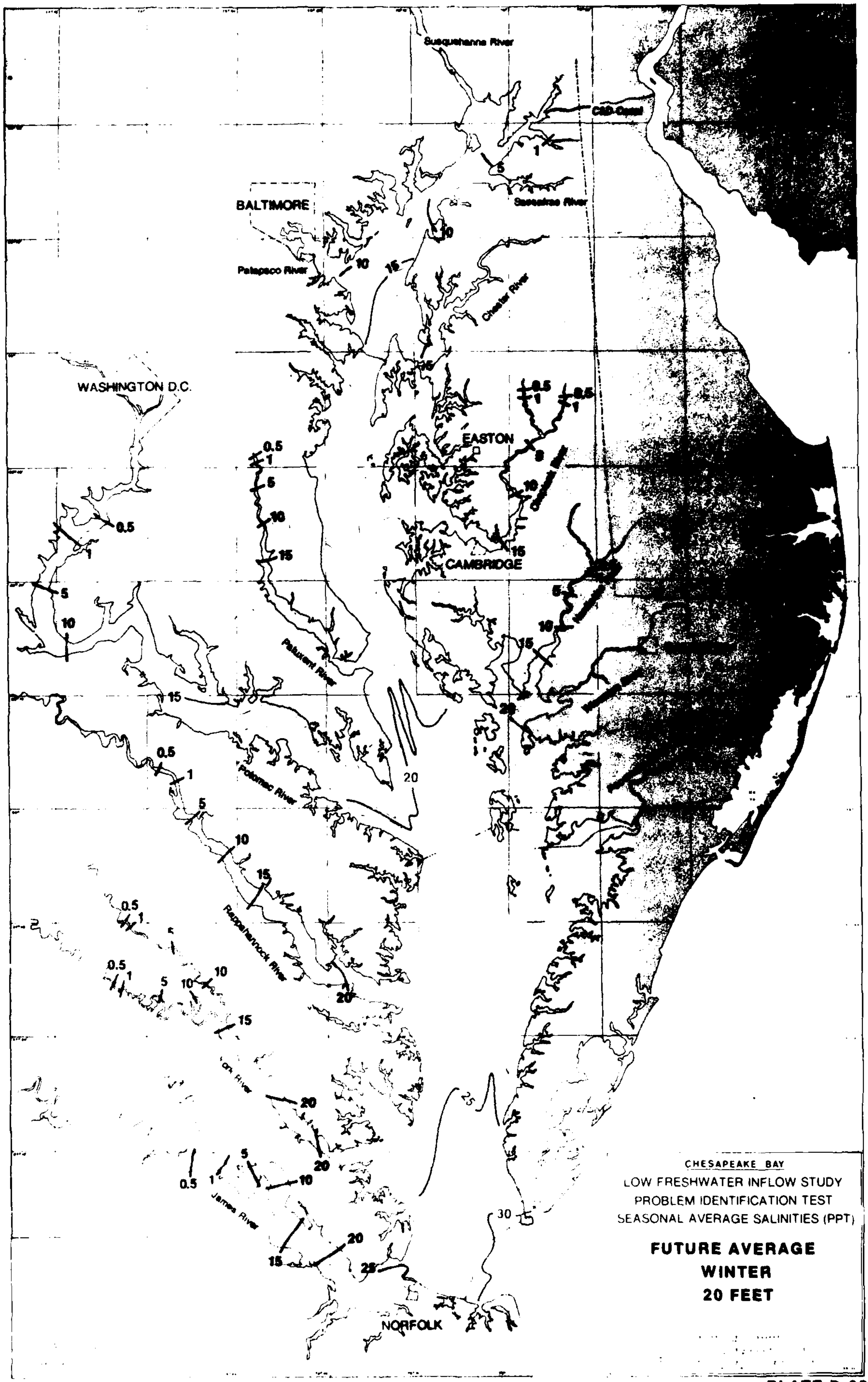

15
15
20
25
30
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE AVERAGE
WINTER
20 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST

PLATE D-67



CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)

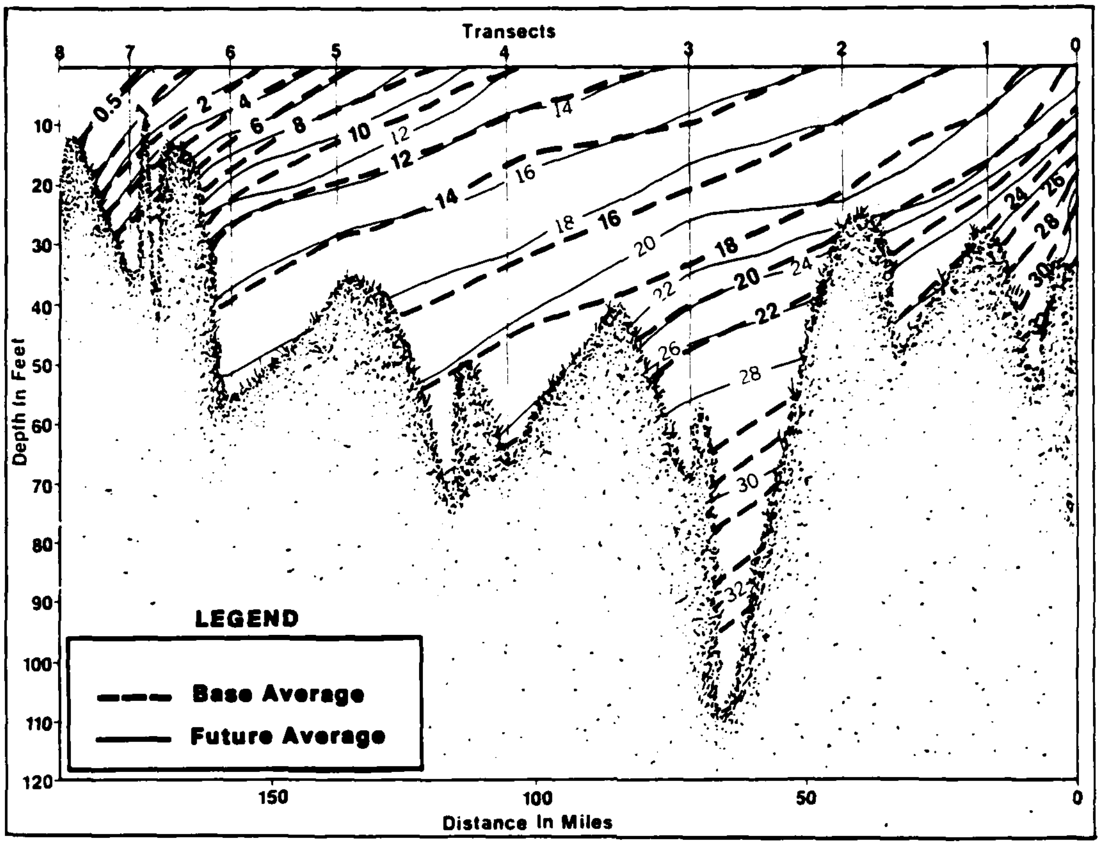
FUTURE AVERAGE
WINTER
20 FEET

PLATE D-68


20
20
25
30
CHESAPEAKE BAY
LOW FRESHWATER INFLOW STUDY
PROBLEM IDENTIFICATION TEST
SEASONAL AVERAGE SALINITIES (PPT)
BASE DROUGHT
WINTER
20 FEET
BASED ON DATA FROM
HYDRAULIC MODEL TEST


BALTIMORE
Patapsco River
WASHINGTON D.C.
EASTON
CAMBRIDGE
NORFOLK
CHESAPEAKE BAY
FRESHWATER INFLOW STUDY
EM IDENTIFICATION TEST
AVERAGE SALINITIES (PPT)
FUTURE DROUGHT
WINTER
20 FEET

PLATE D-70



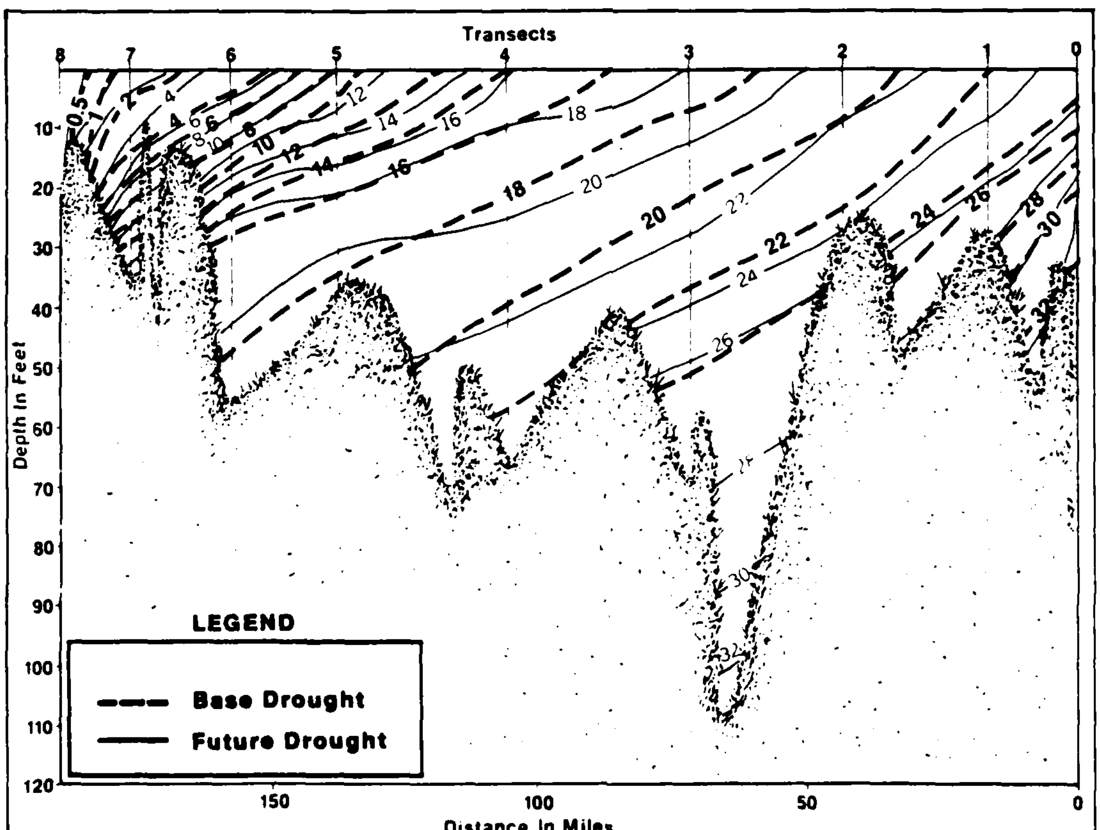
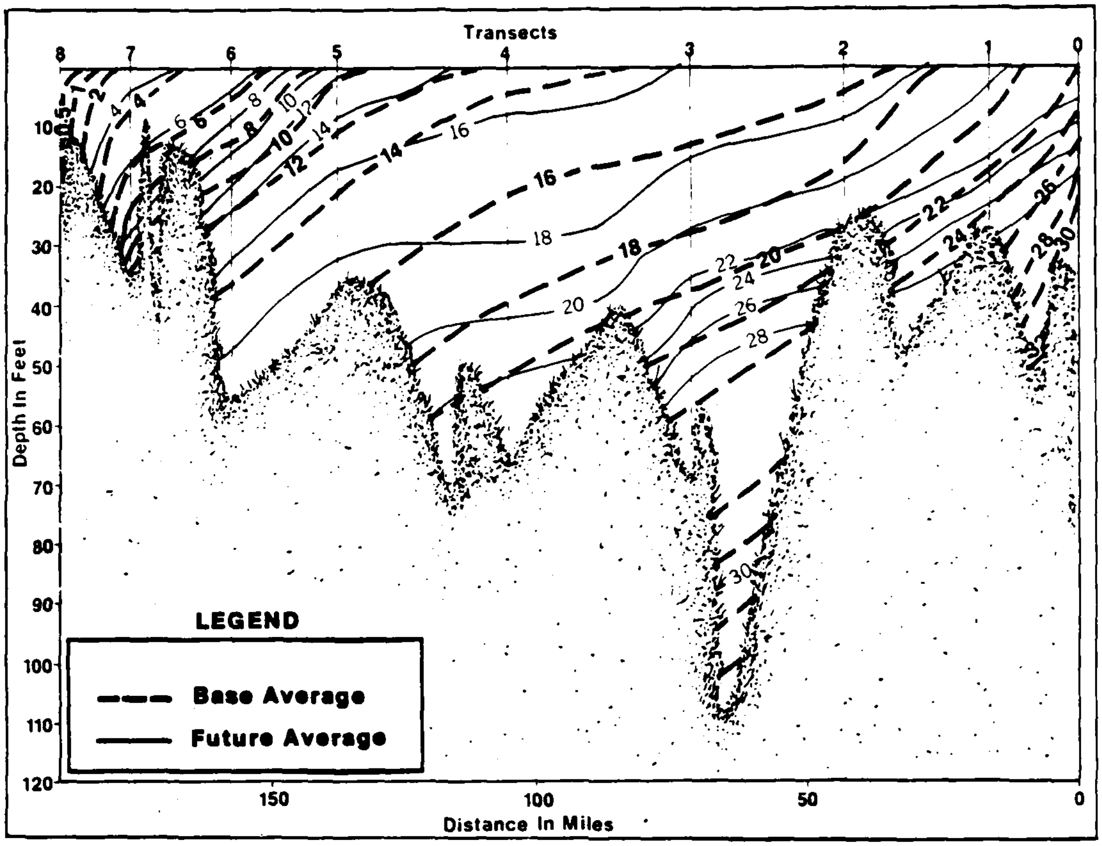


PLATE D-71 LONGITUDINAL SALINITY PROFILES - MAIN BAY - SPRING



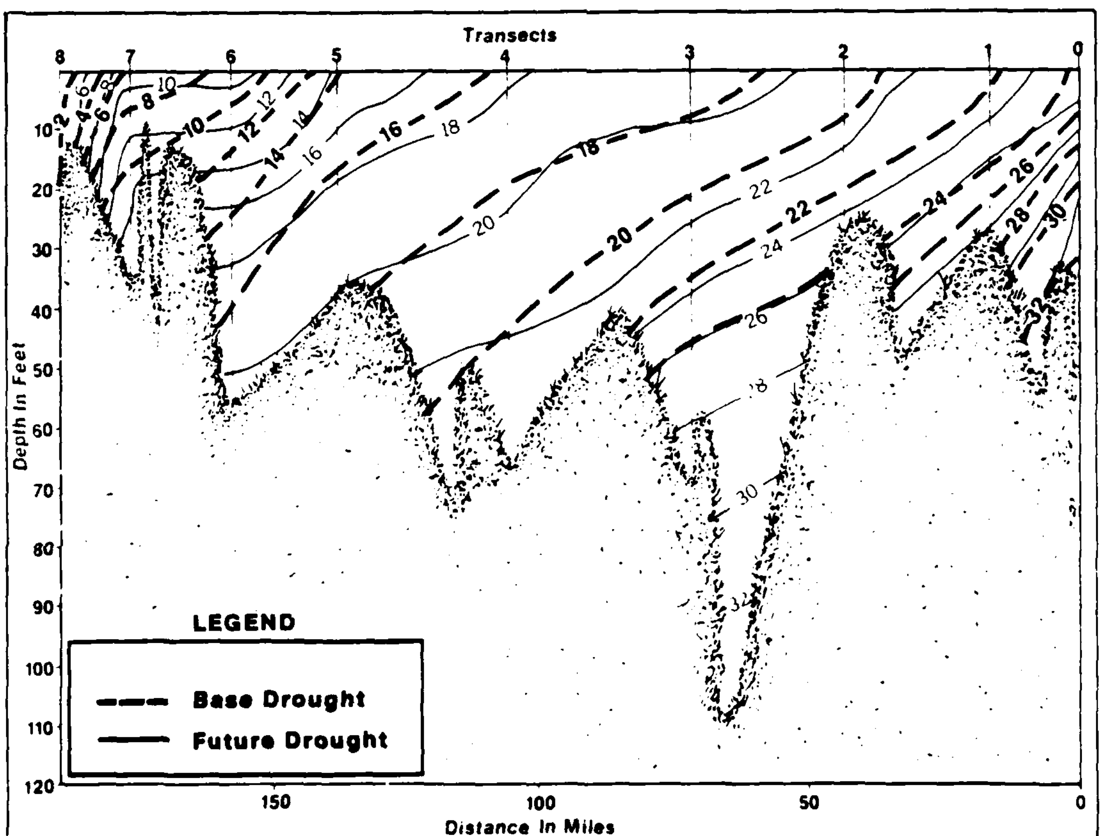
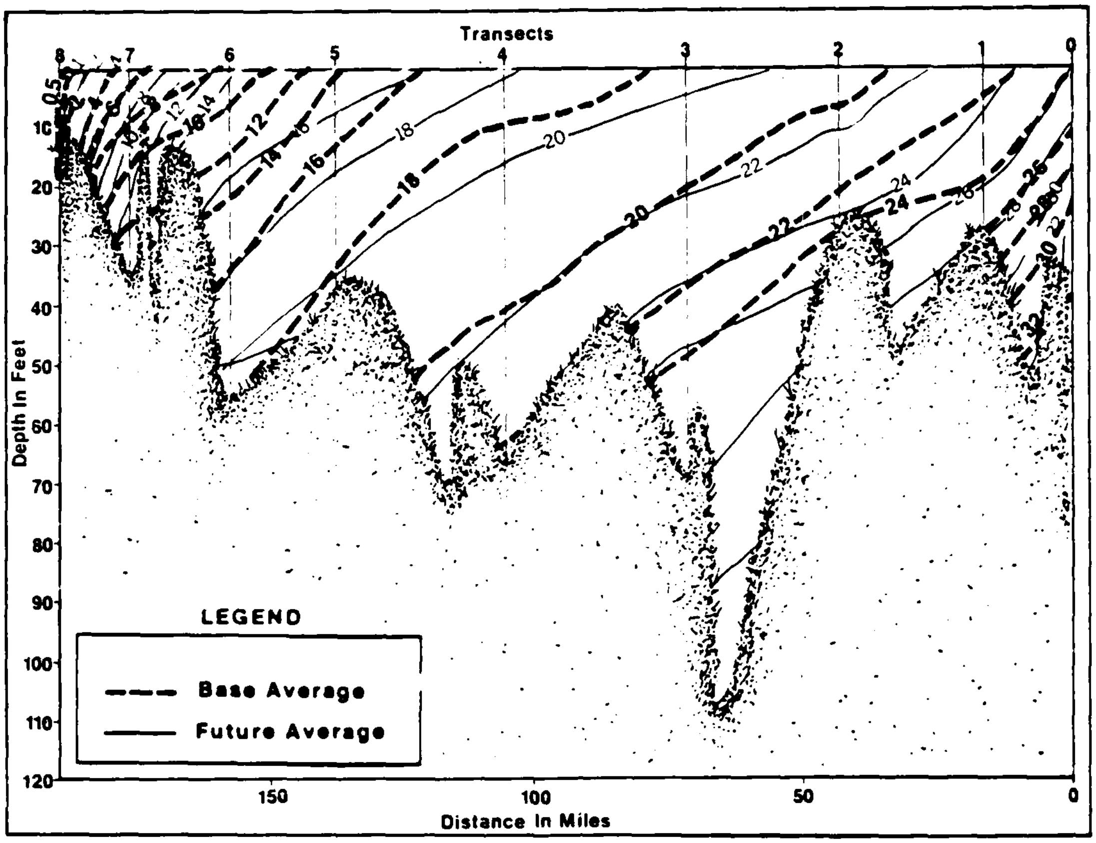


PLATE D-72 LONGITUDINAL SALINITY PROFILES - MAIN BAY - SUMMER



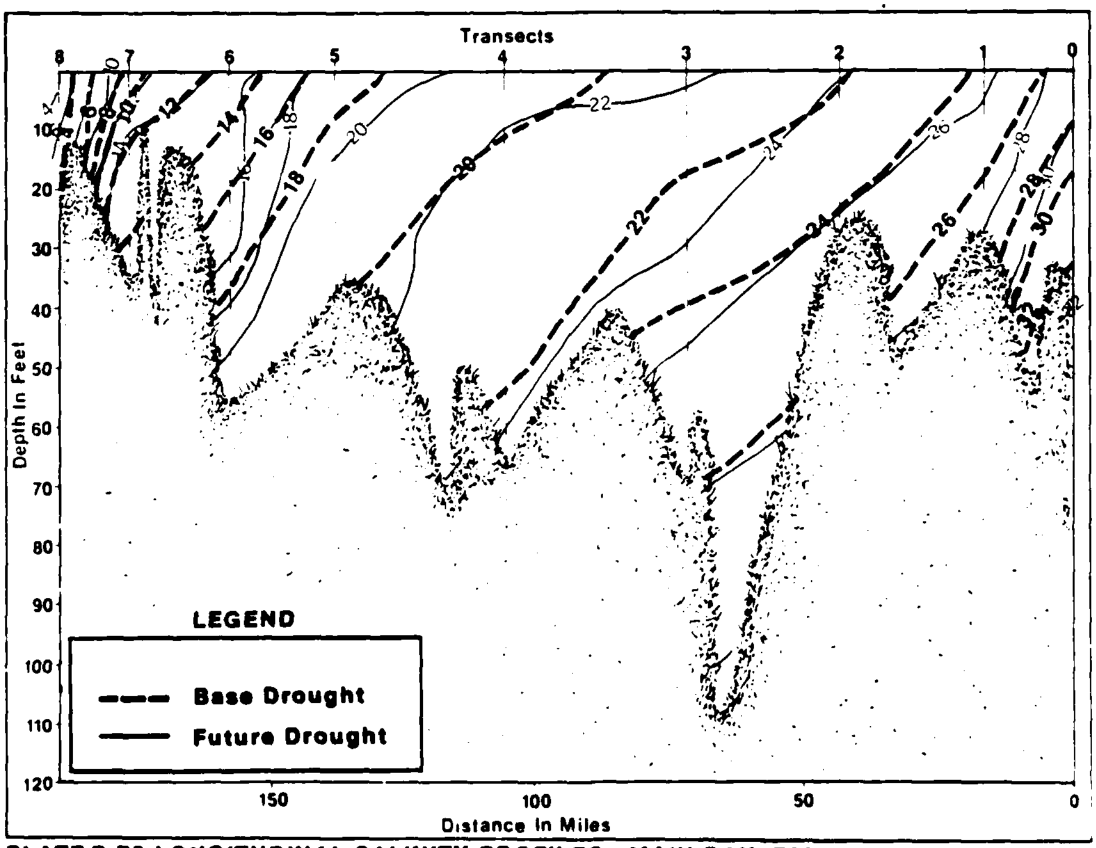


PLATE D-73 LONGITUDINAL SALINITY PROFILES - MAIN BAY - FALL

AD-A161 481 CHESAPEAKE BAY LOW FRESHWATER INFLOW STUDY APPENDIX B 5/5
PLAN FORMULATION AP..(U) CORPS OF ENGINEERS BALTIMORE
MD BALTIMORE DISTRICT SEP 84 CHB-84-L-APP-B-C-D

UNCLASSIFIED F/G 8/10 NL

END
FILMED
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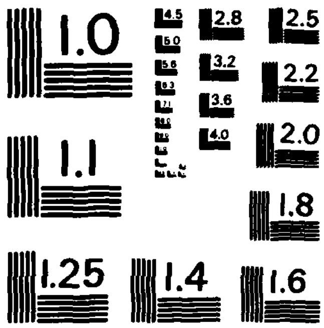
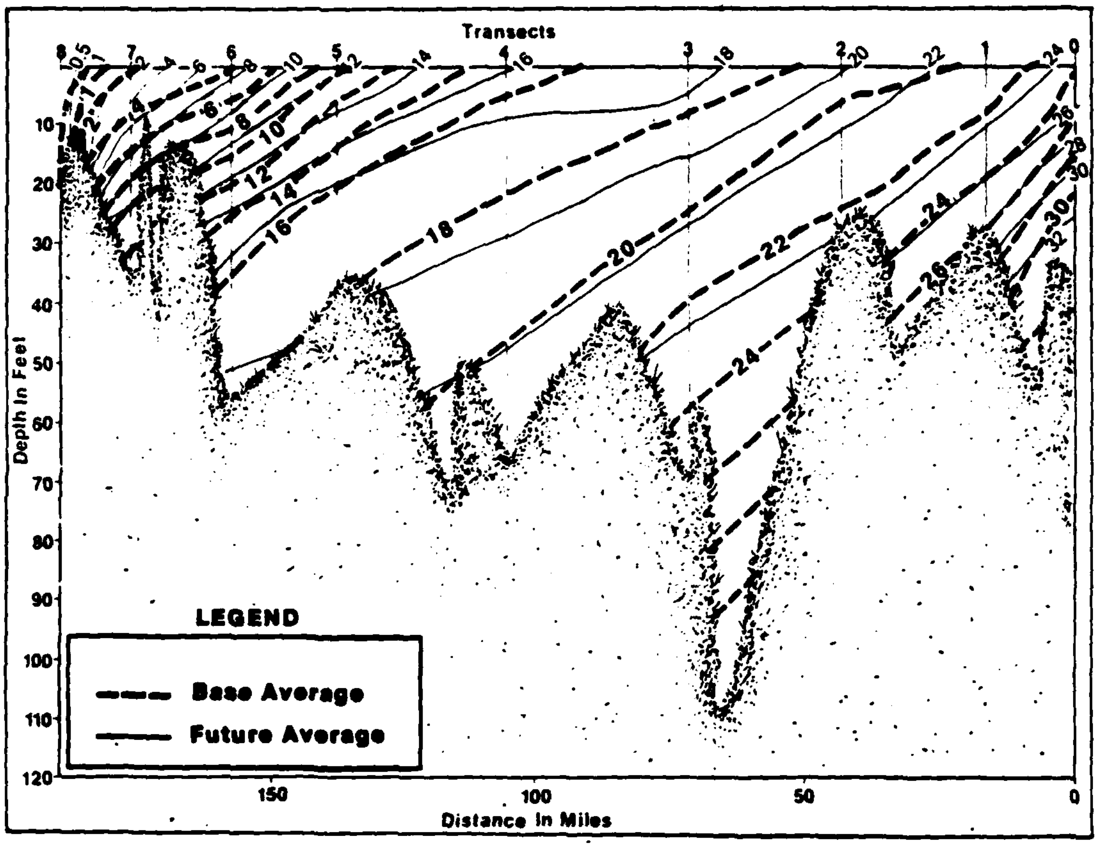

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0



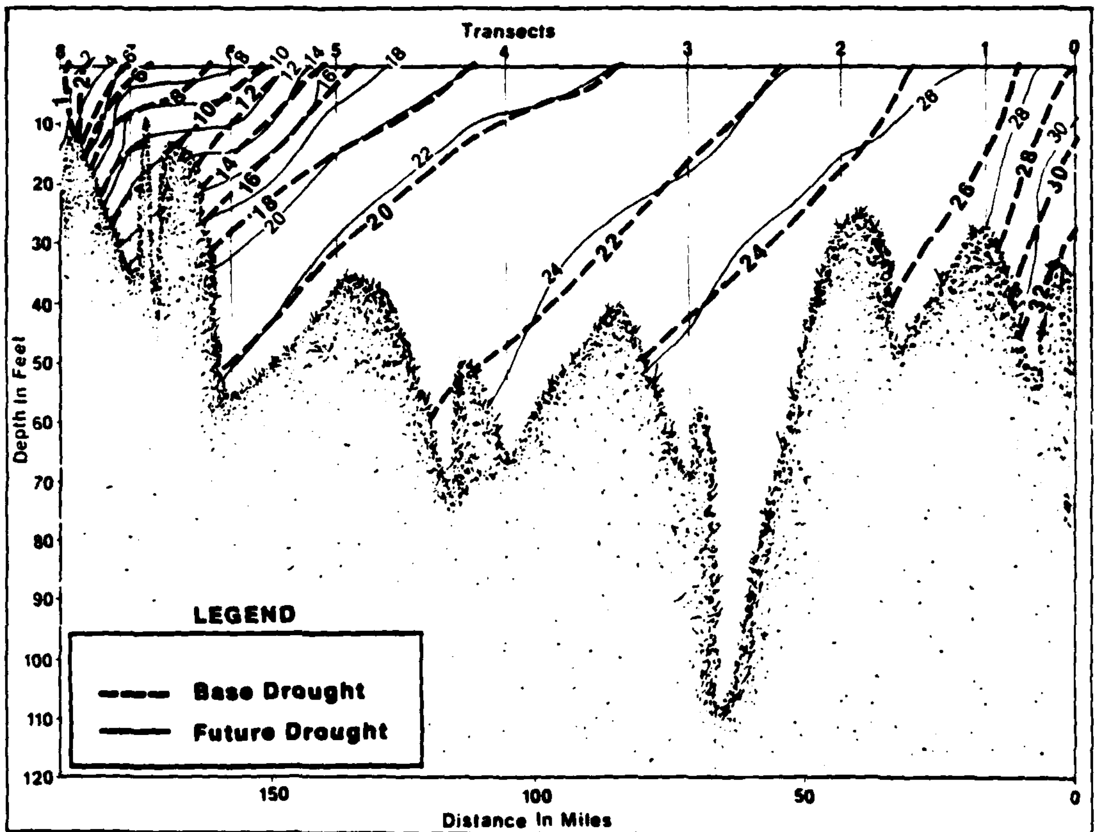
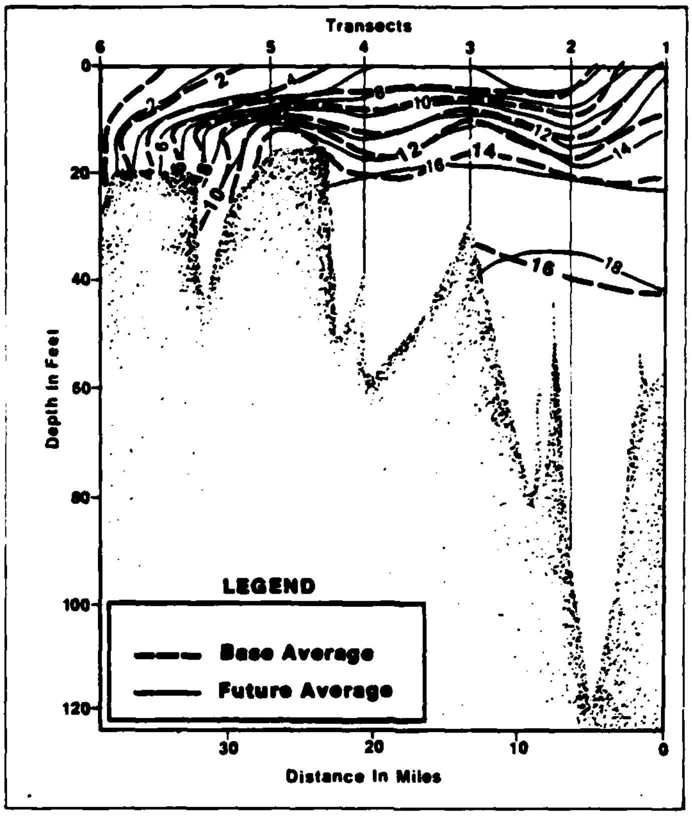


PLATE D-74 LONGITUDINAL SALINITY PROFILES - MAIN BAY - WINTER



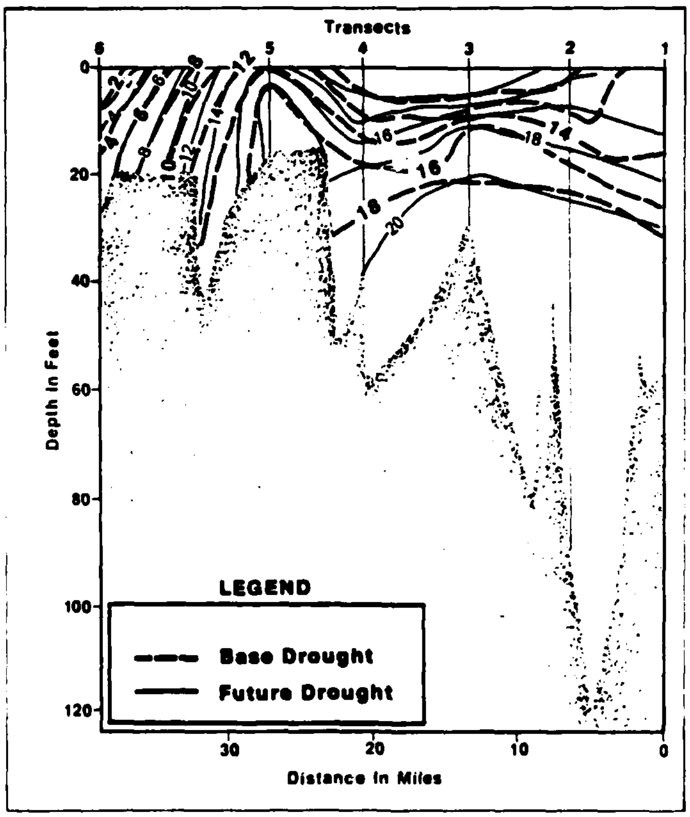
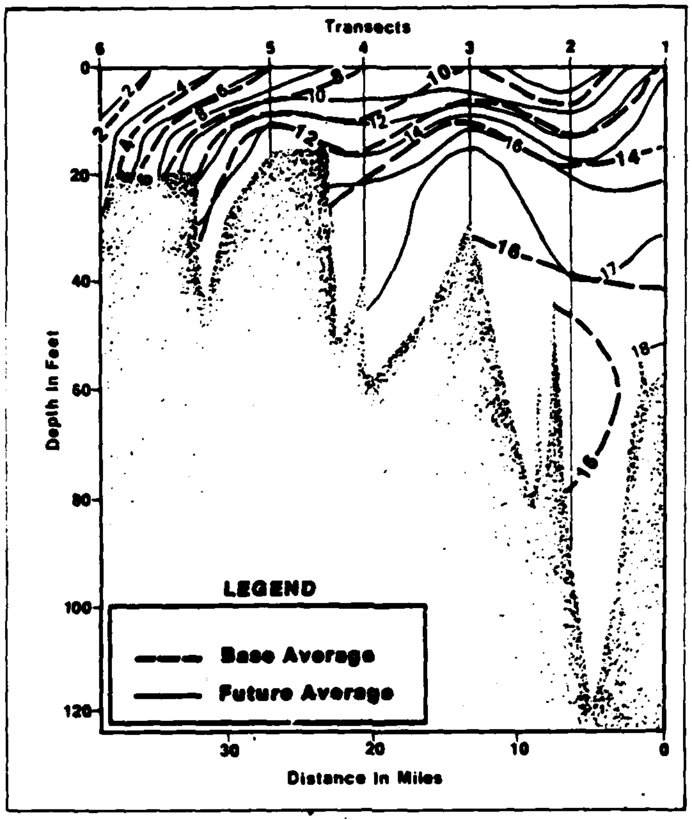


PLATE D-75
LONGITUDINAL SALINITY PROFILES - PATUXENT - SPRING



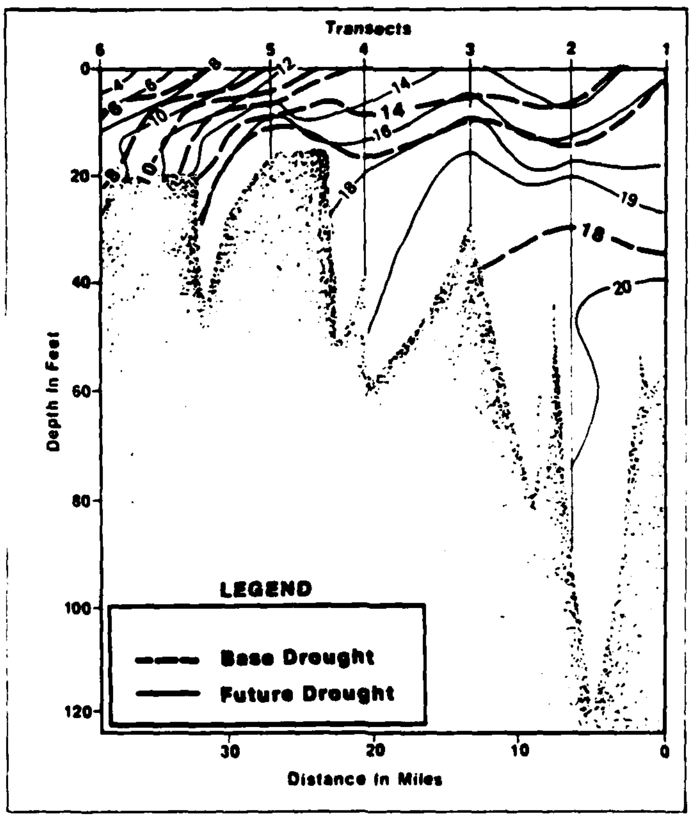
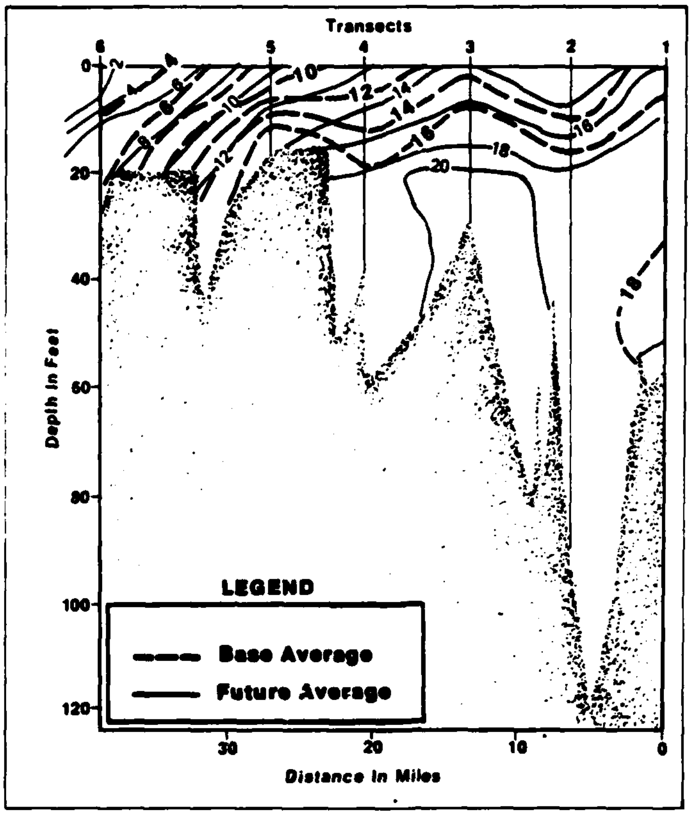


PLATE D- 76
LONGITUDINAL SALINITY PROFILES - PATUXENT - SUMMER



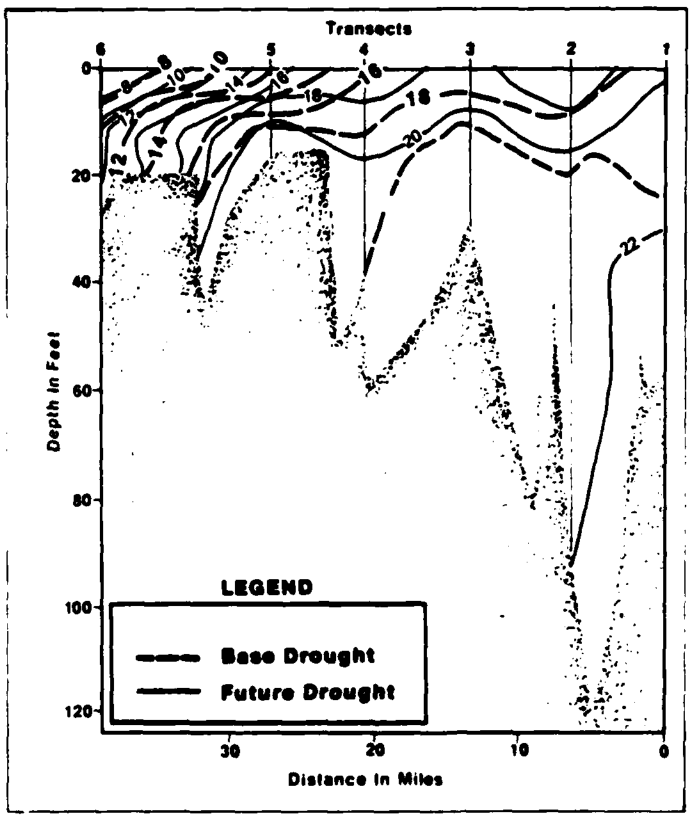
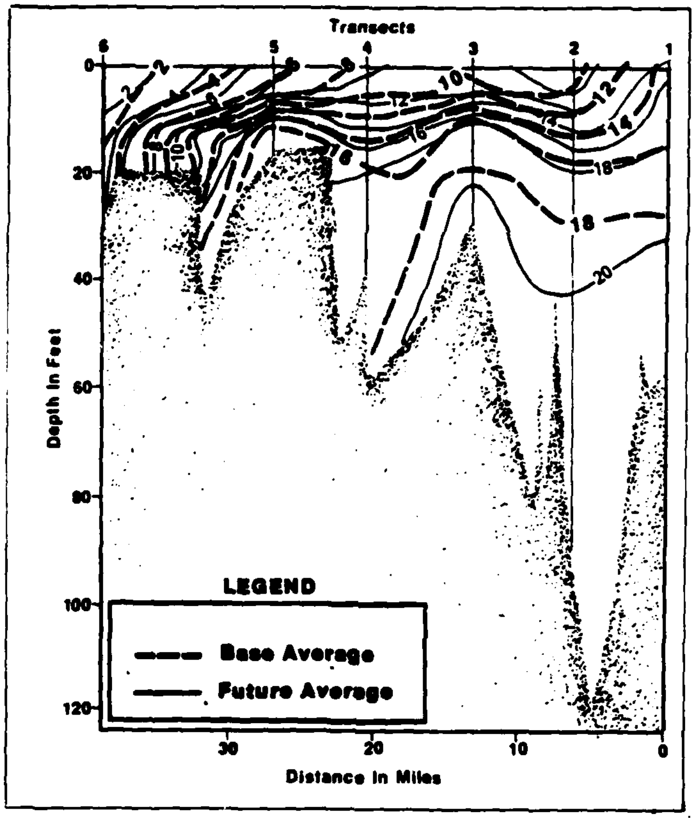


PLATE D-77
LONGITUDINAL SALINITY PROFILES - PATUXENT - FALL



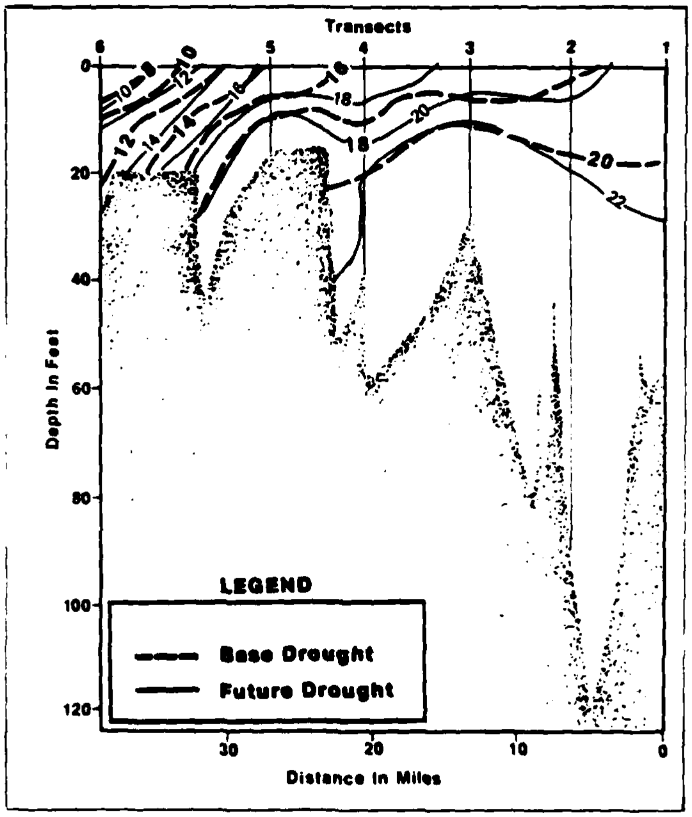
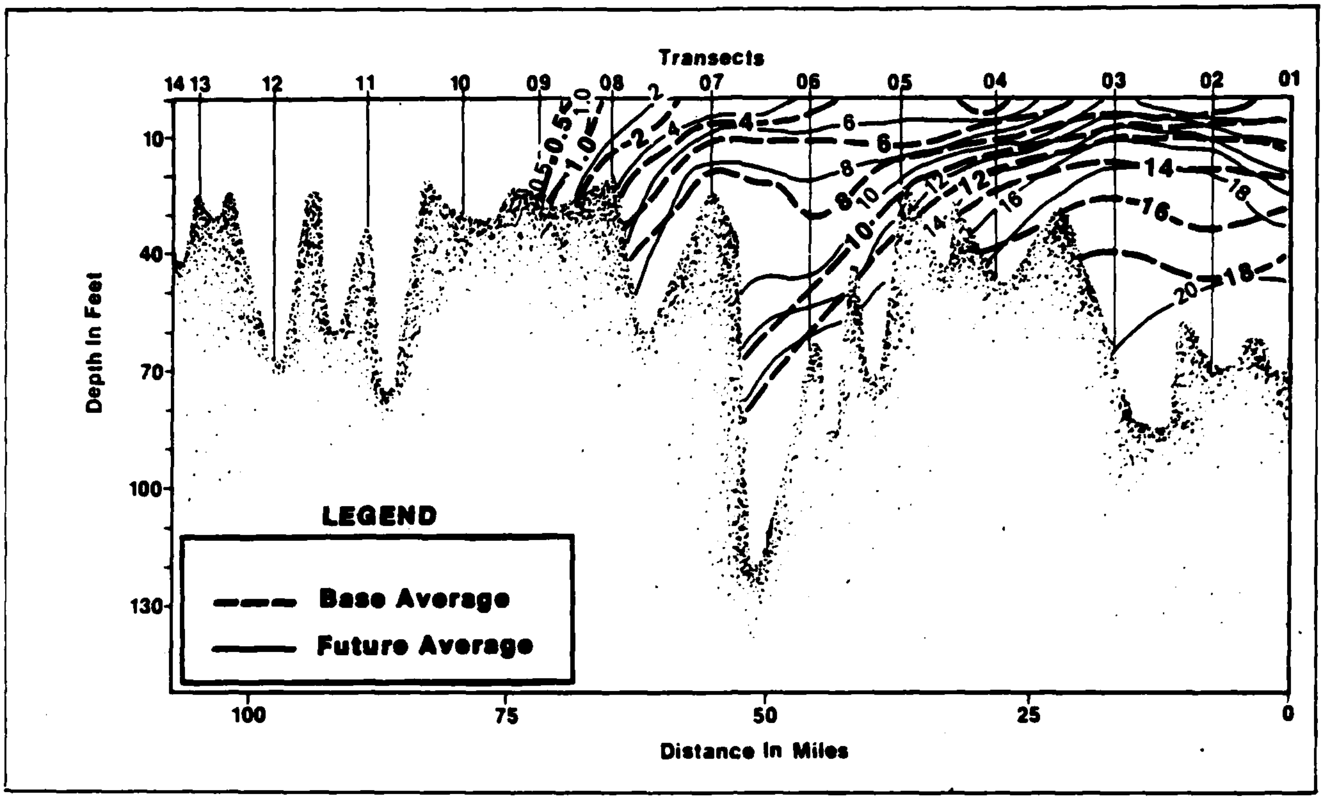


PLATE D-78

LONGITUDINAL SALINITY PROFILES - PATUXENT-WINTER



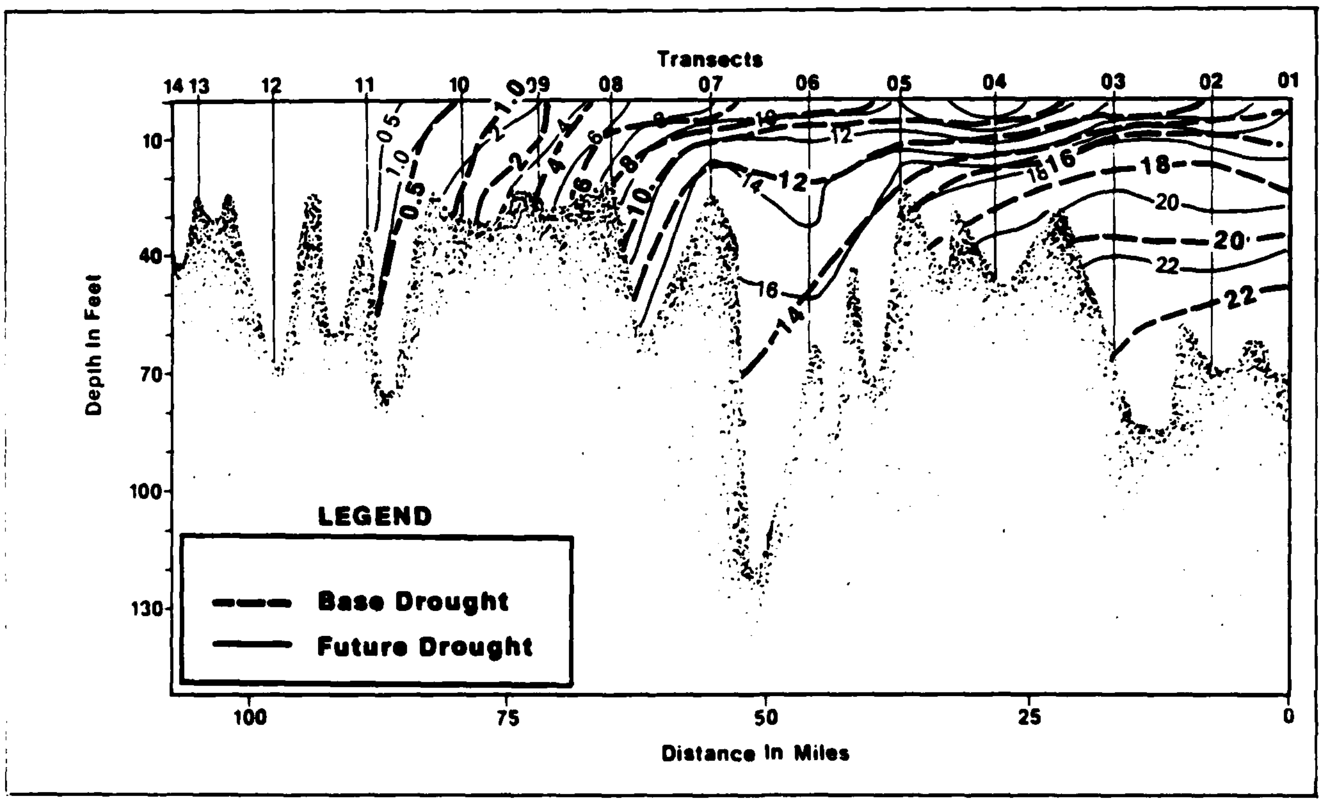
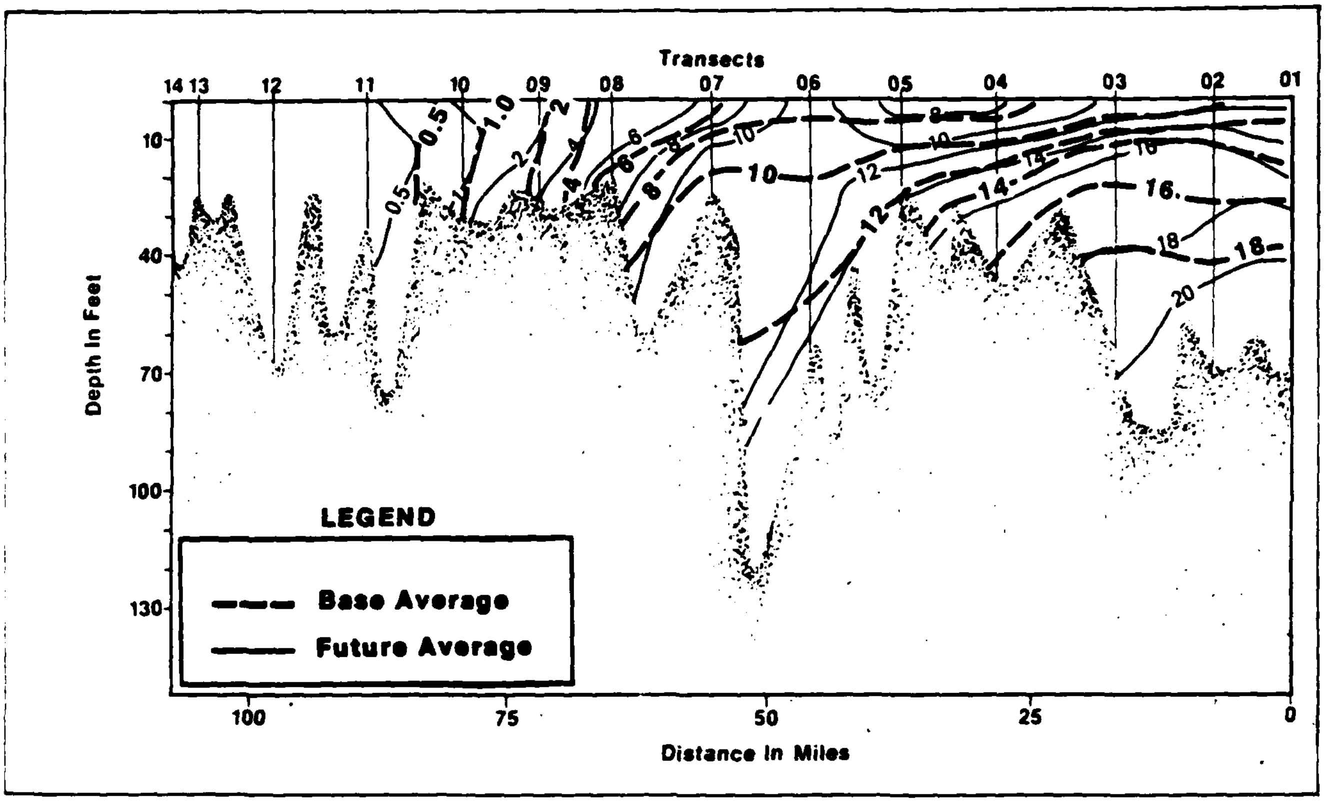


PLATE D-79 LONGITUDINAL SALINITY PROFILES - POTOMAC-SPRING



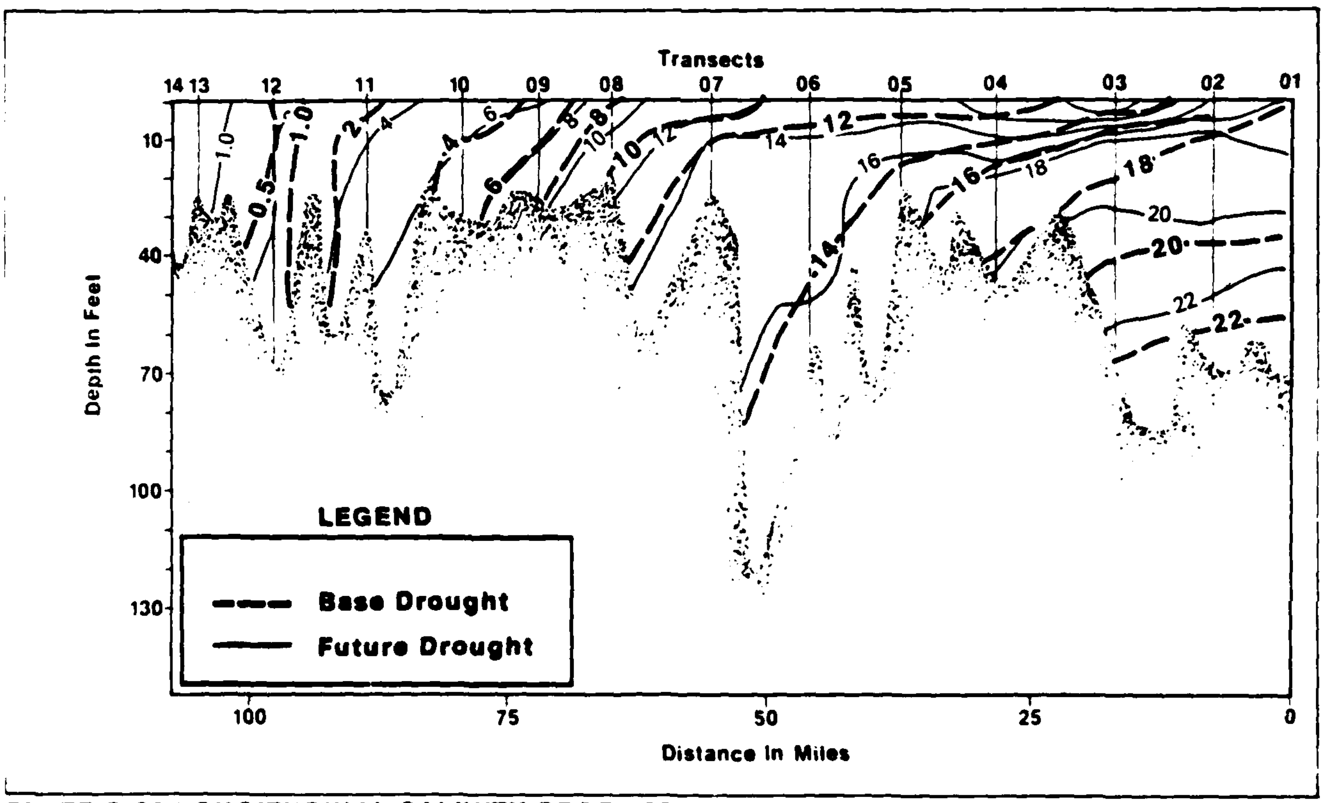
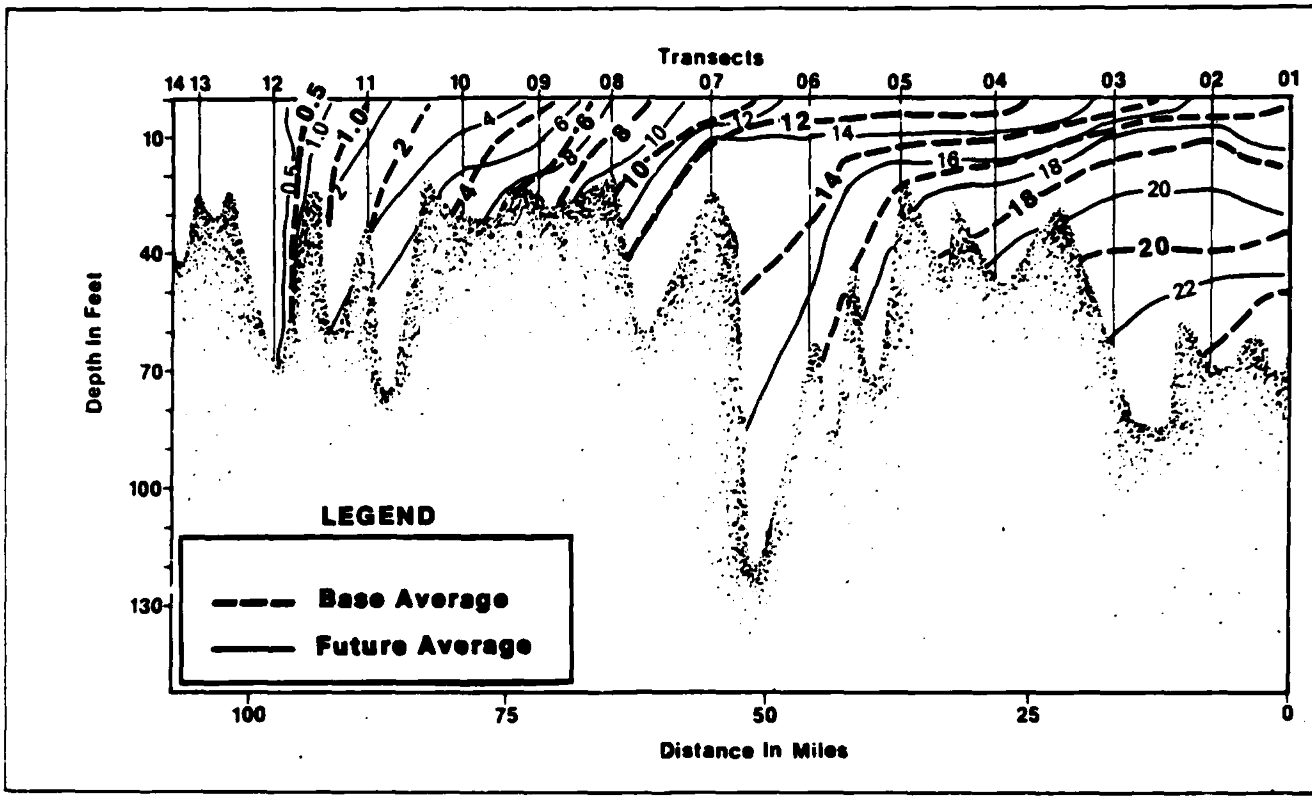


PLATE D-80 LONGITUDINAL SALINITY PROFILES - POTOMAC - SUMMER



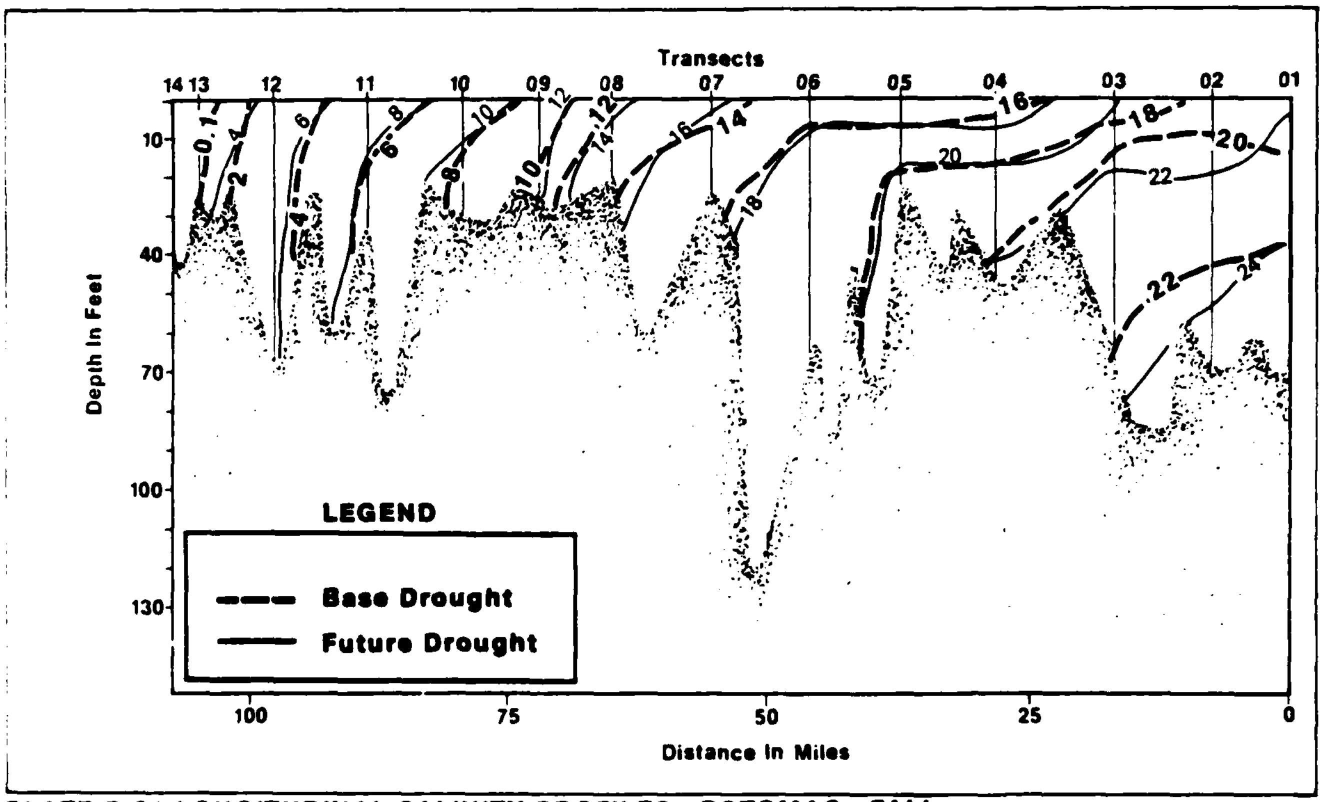
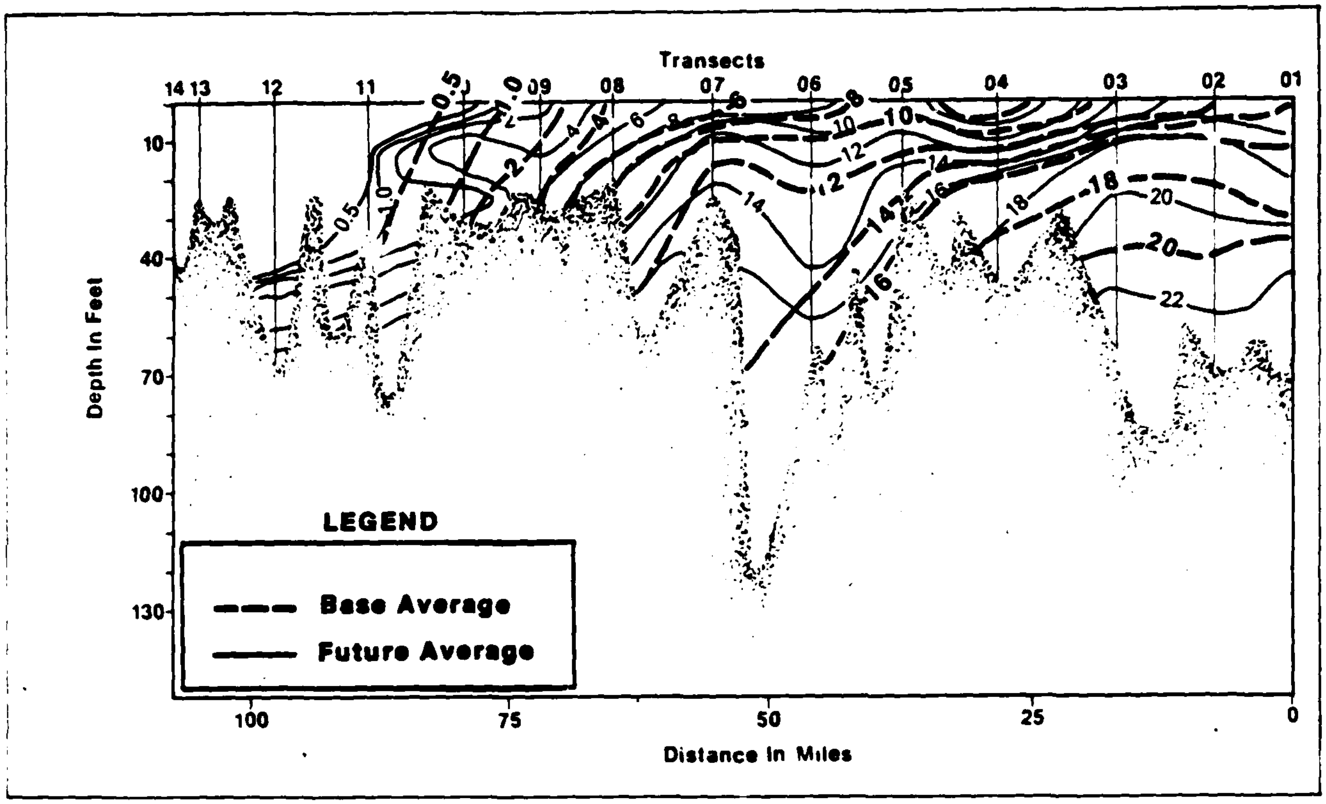


PLATE D-81 LONGITUDINAL SALINITY PROFILES - POTOMAC - FALL



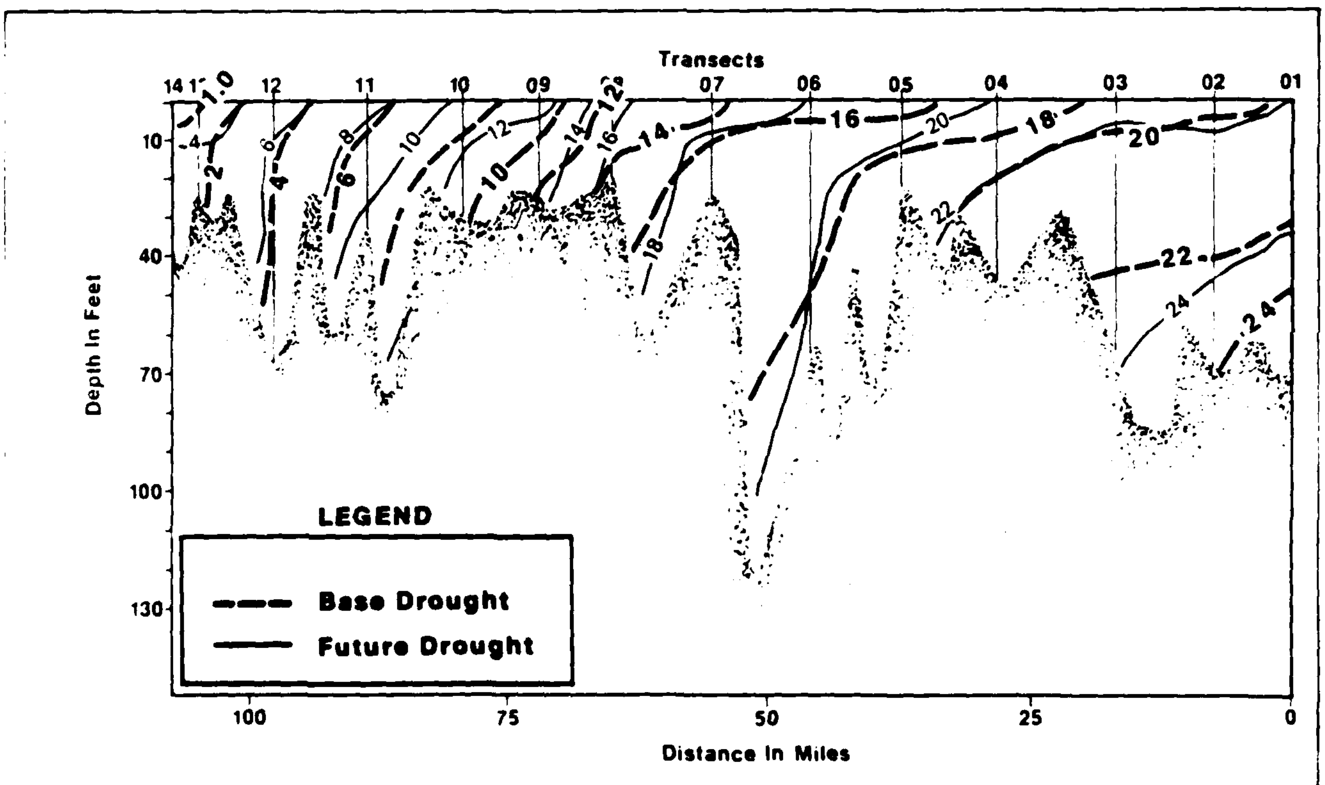
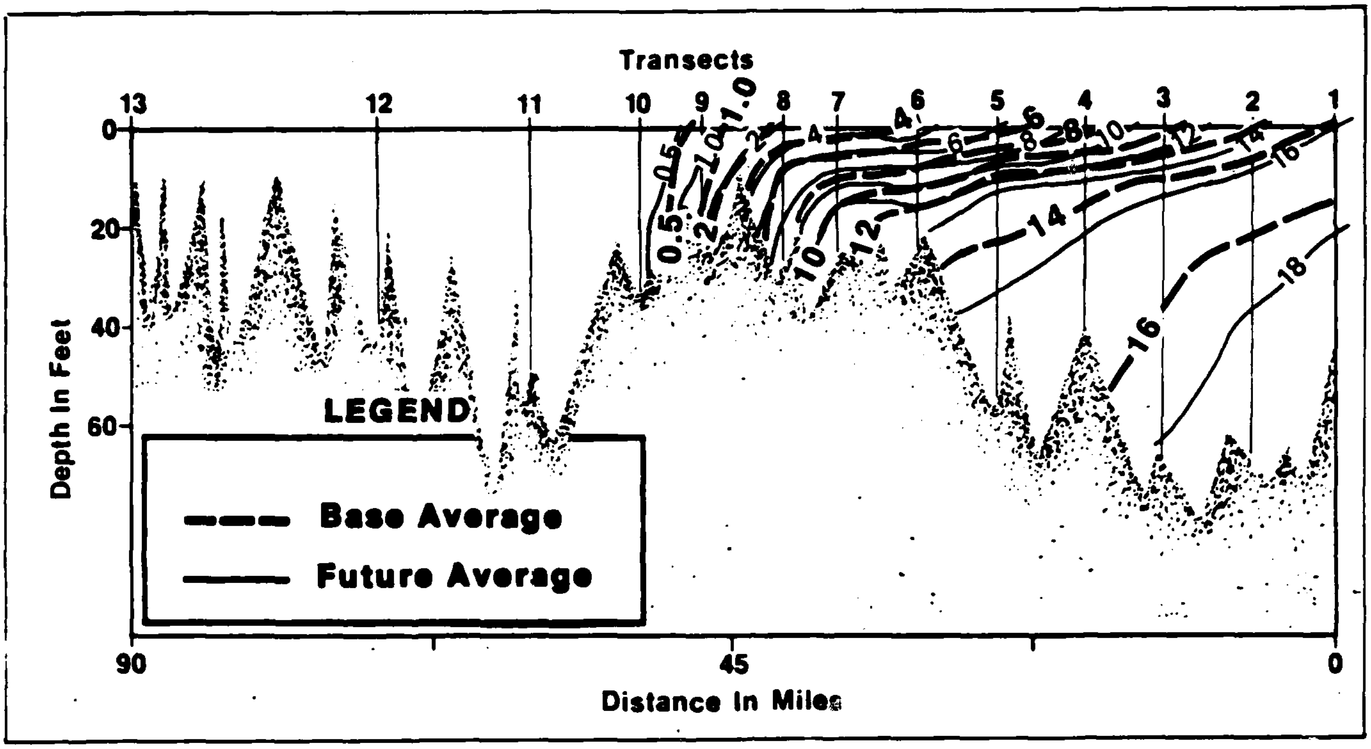


PLATE D-82 LONGITUDINAL SALINITY PROFILES - POTOMAC - WINTER



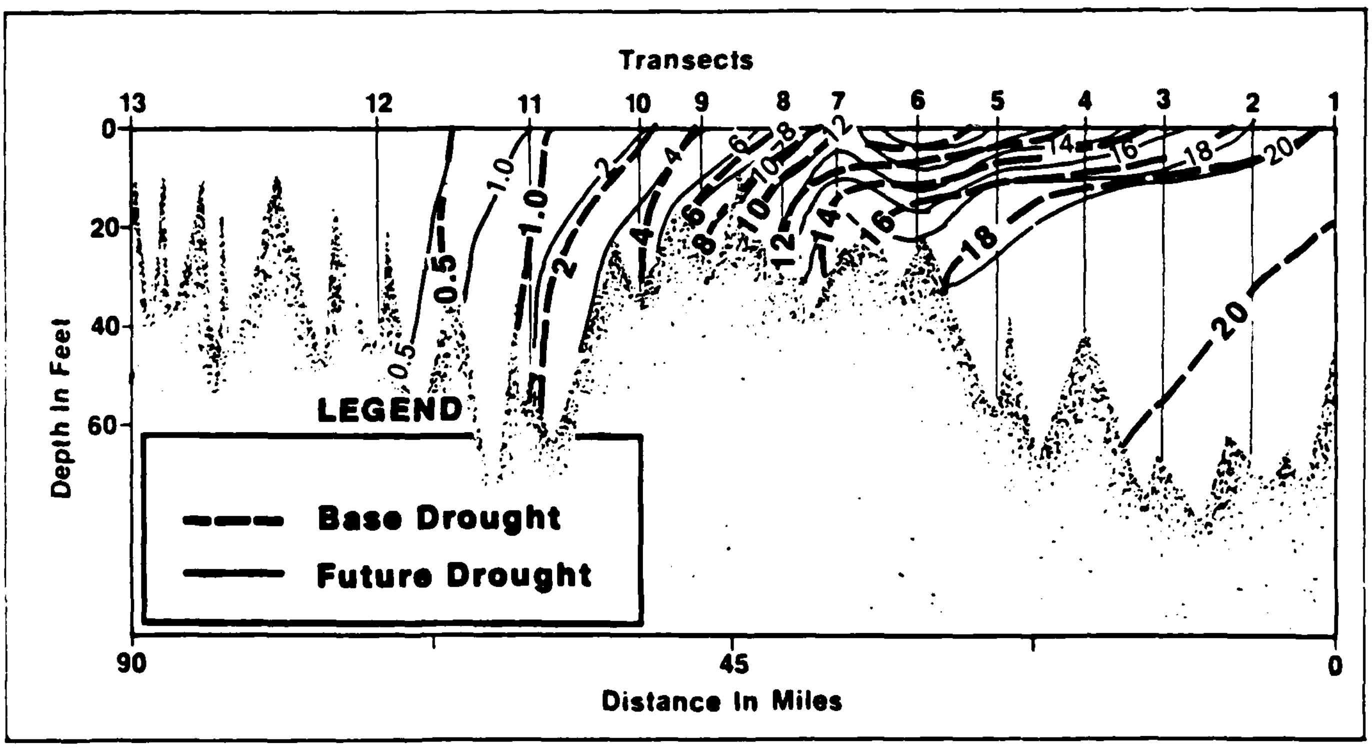
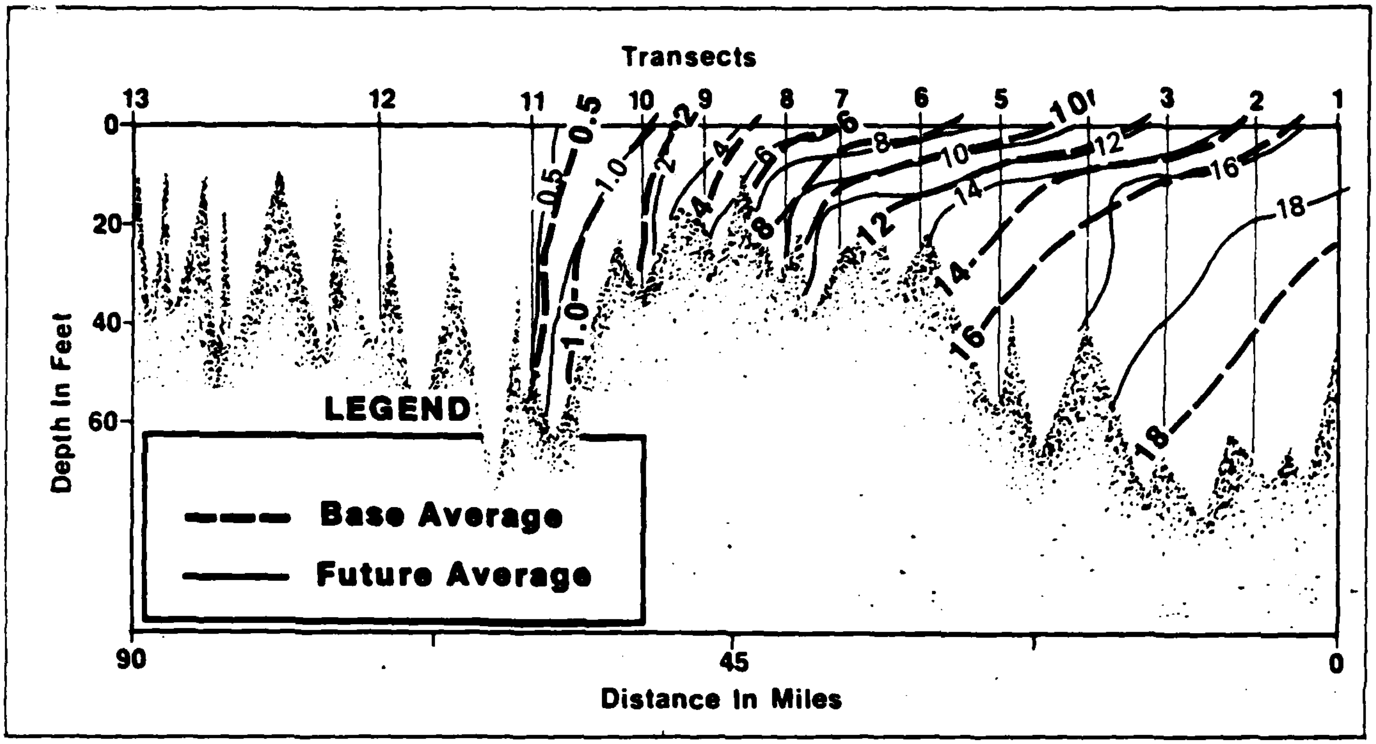


PLATE D-83 LONGITUDINAL SALINITY PROFILES - RAPPAHANNOCK - SPRING



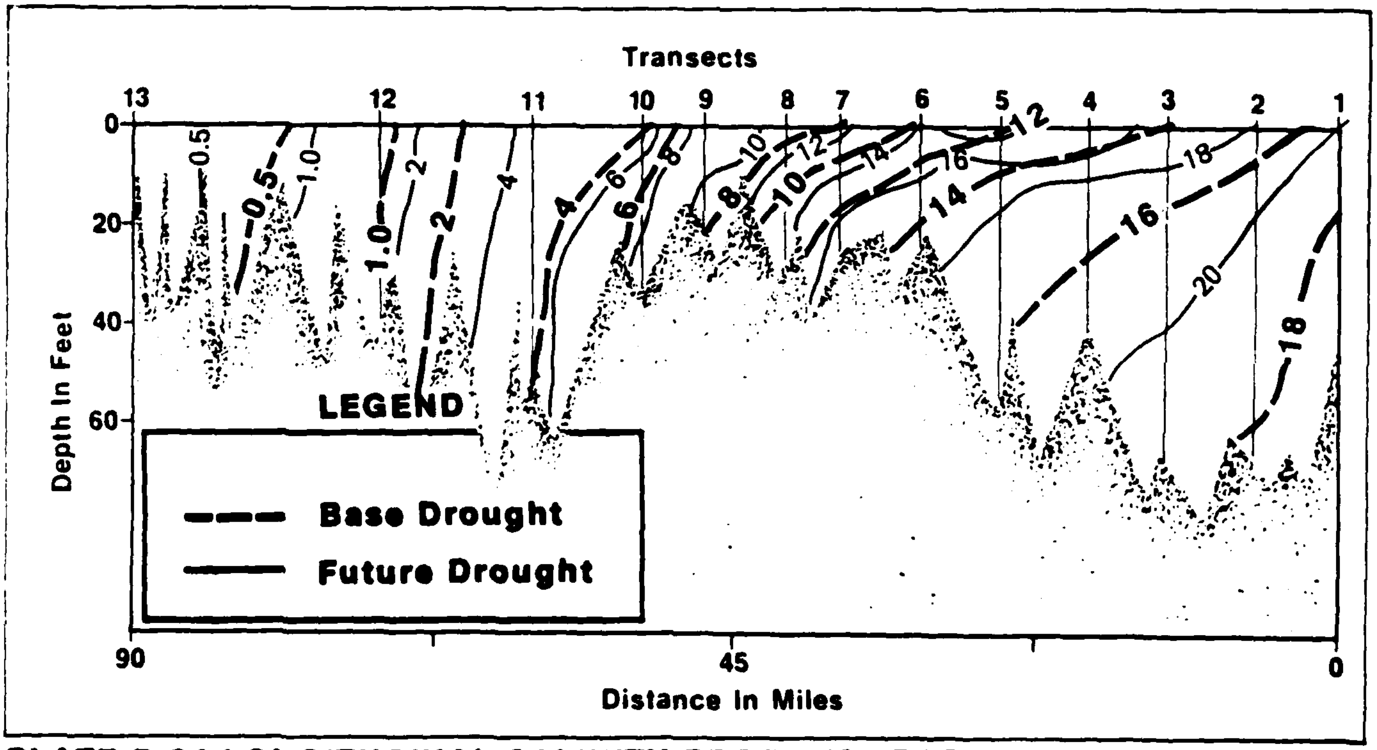
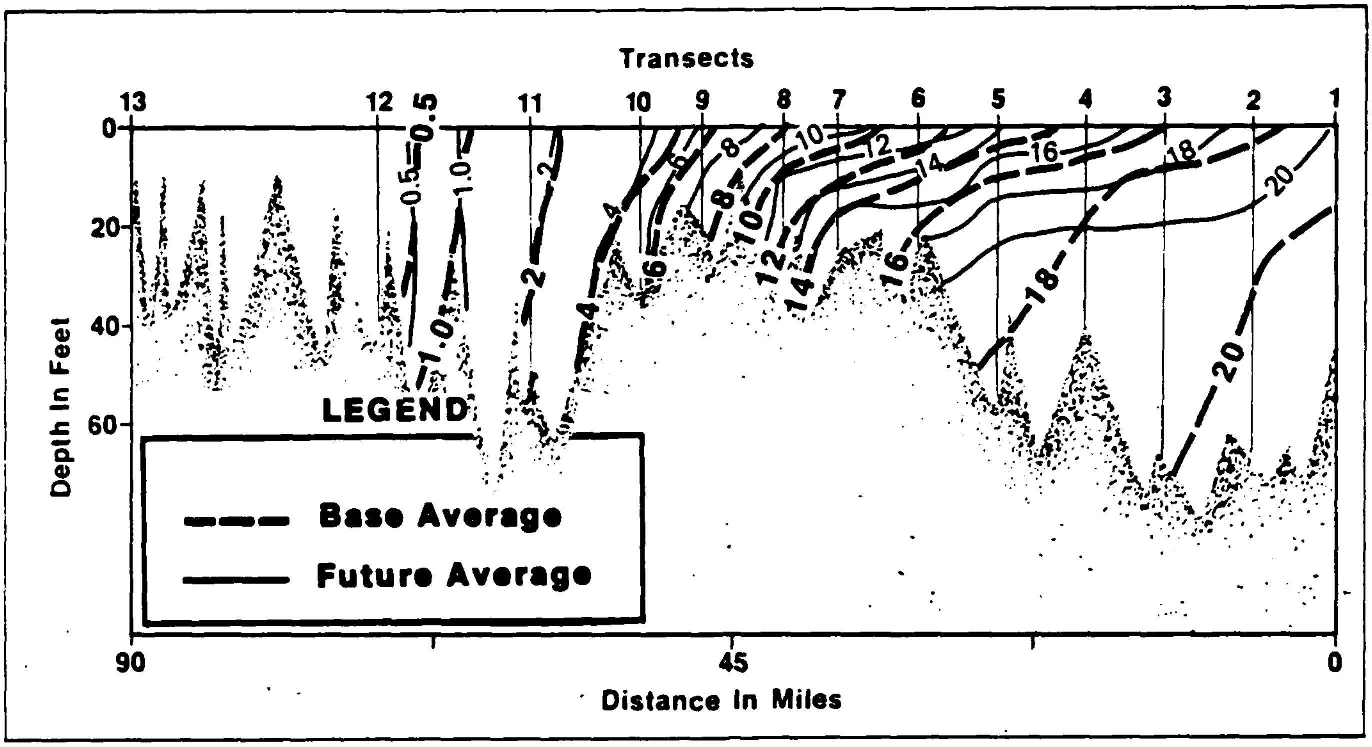


PLATE D-84 LONGITUDINAL SALINITY PROFILES- RAPPAHANNOCK-SUMMER



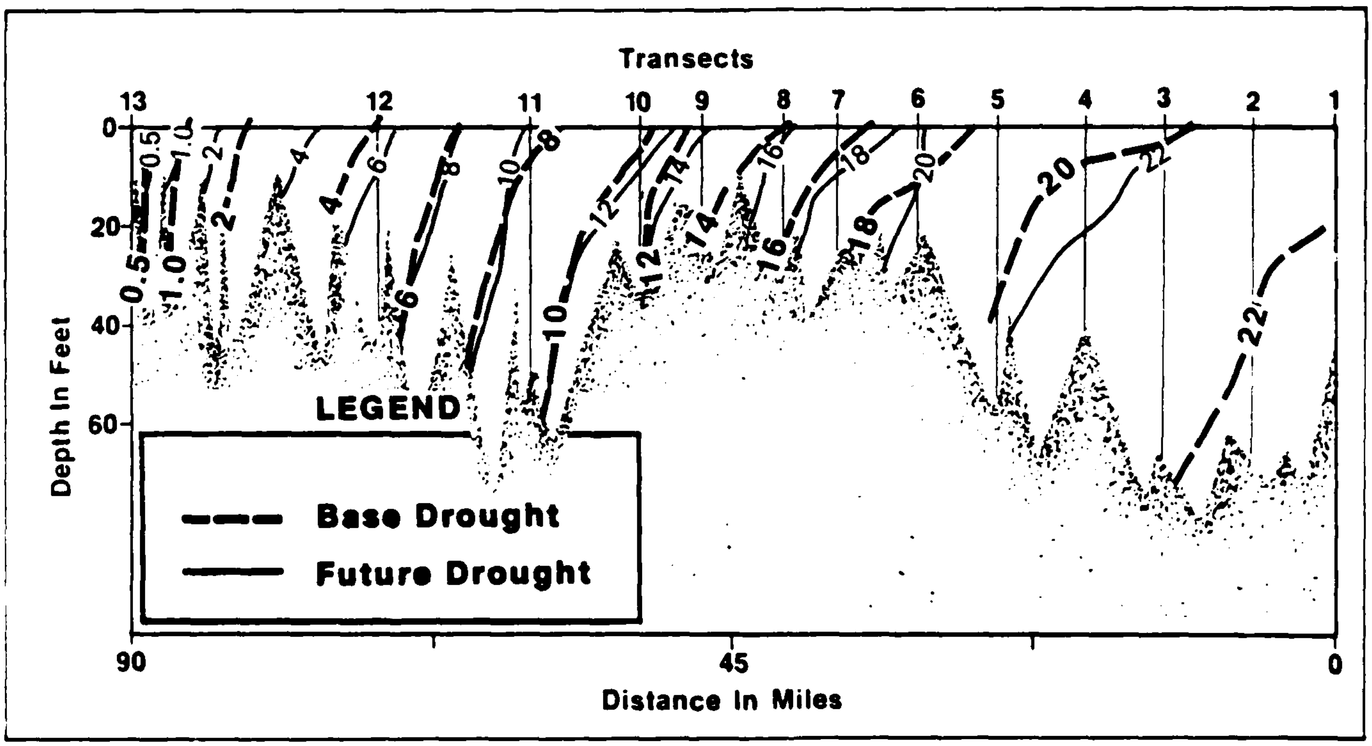
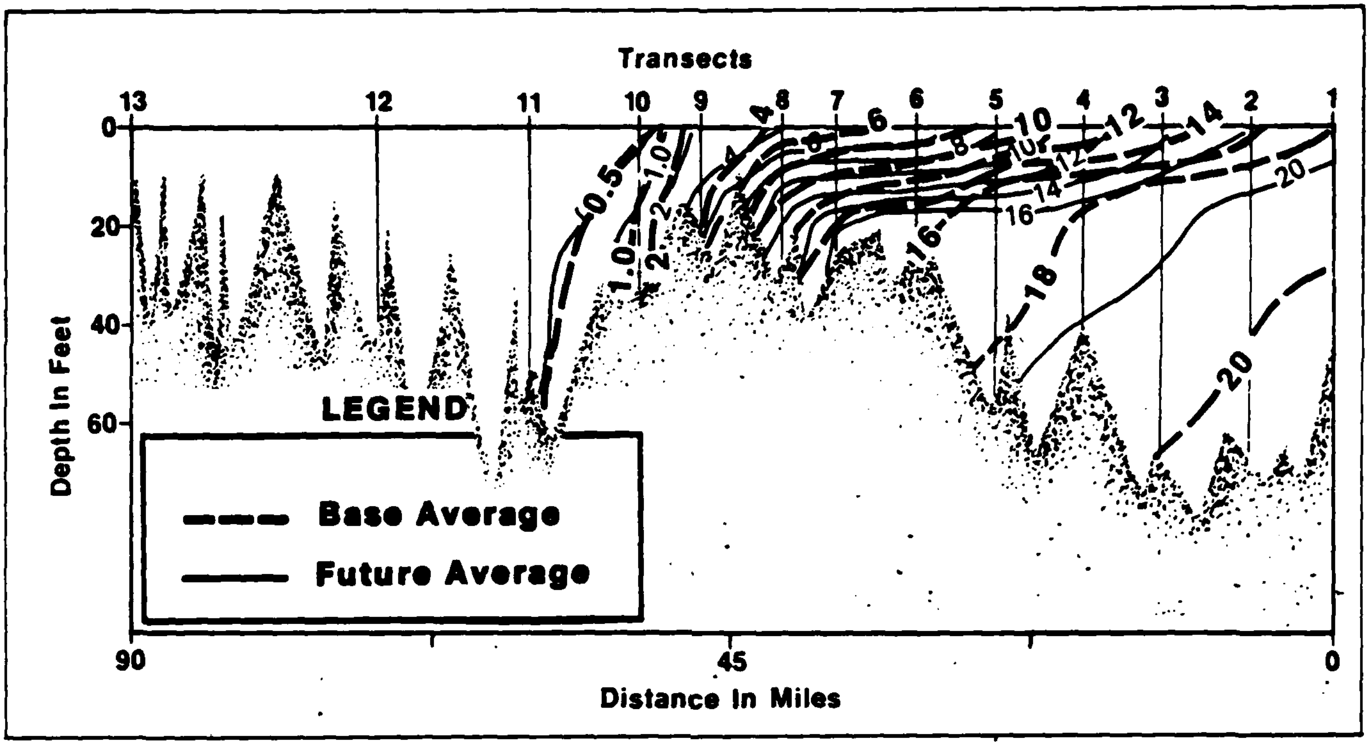


PLATE D-85 LONGITUDINAL SALINITY PROFILES - RAPPAHANNOCK - FALL



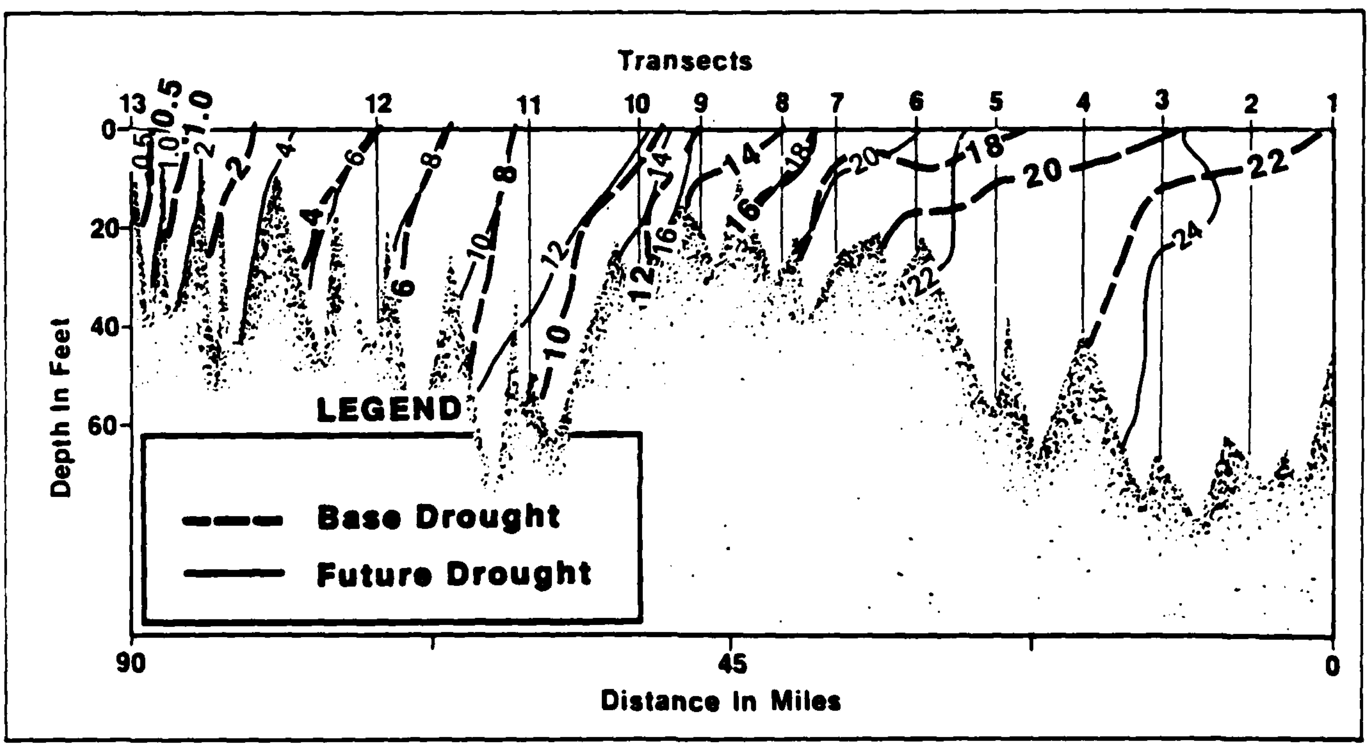
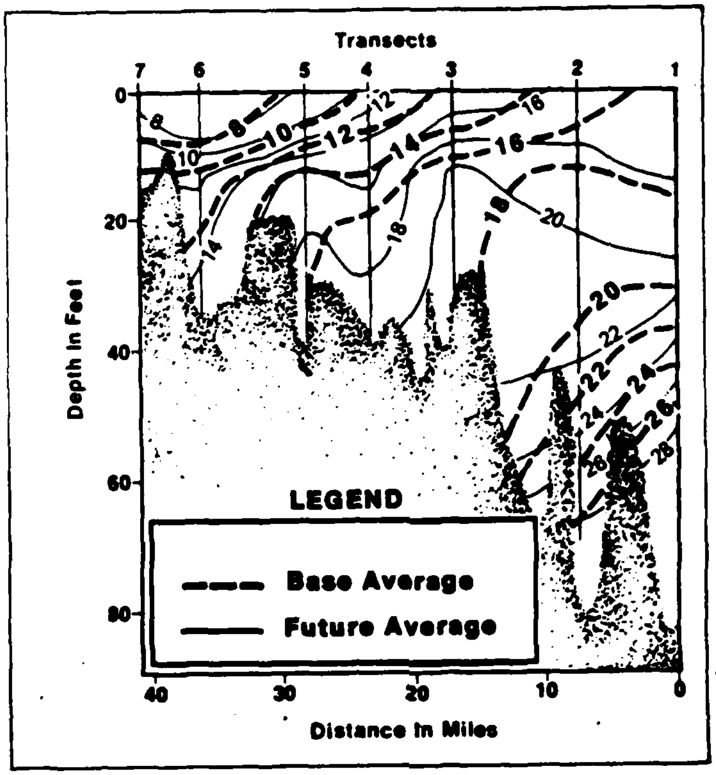


PLATE D-86 LONGITUDINAL SALINITY PROFILES - RAPPAHANNOCK - WINTER



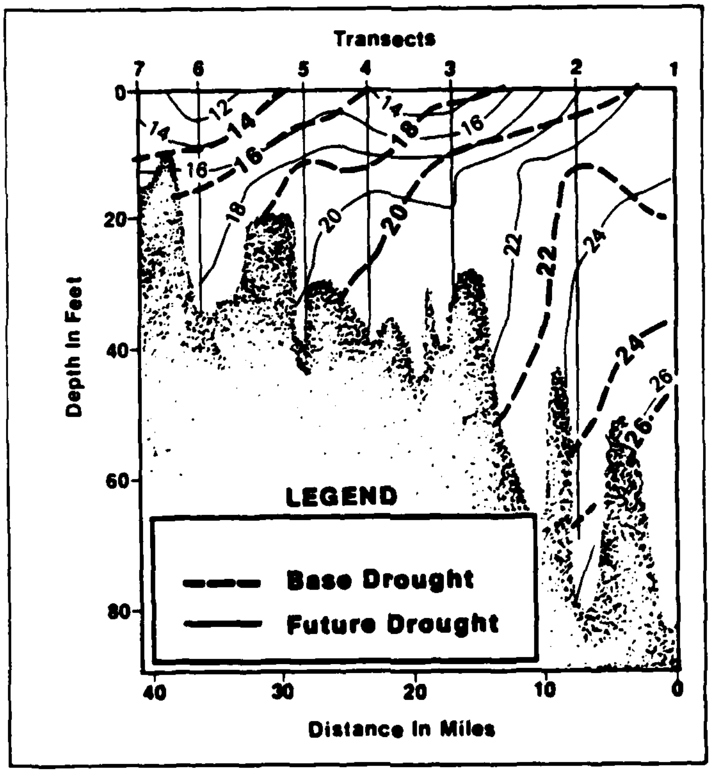
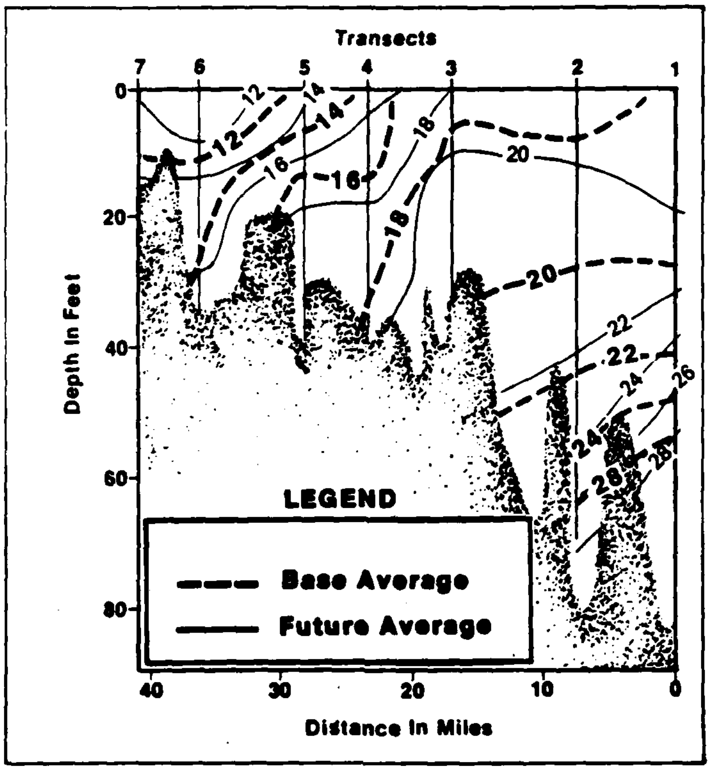


PLATE D-87
LONGITUDINAL SALINITY PROFILES - YORK - SPRING



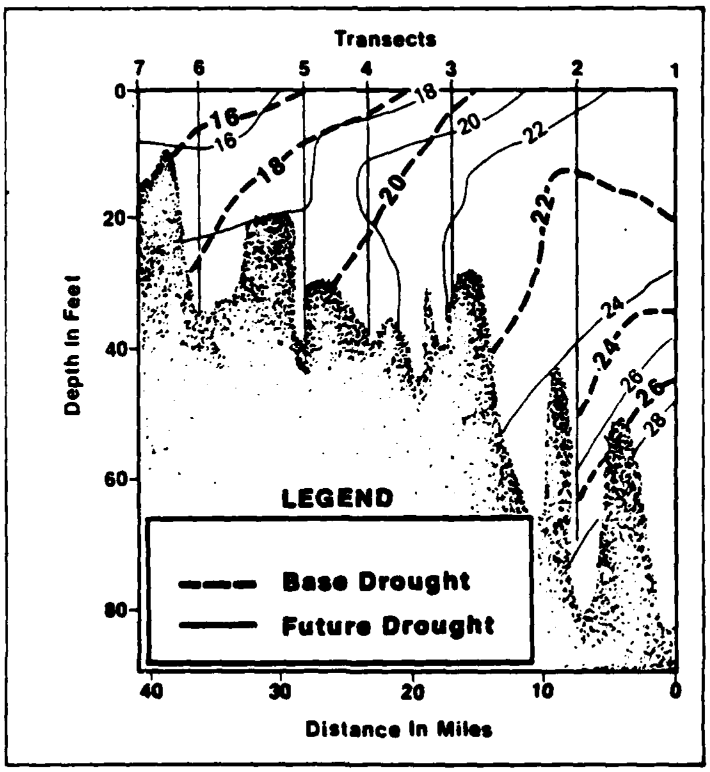
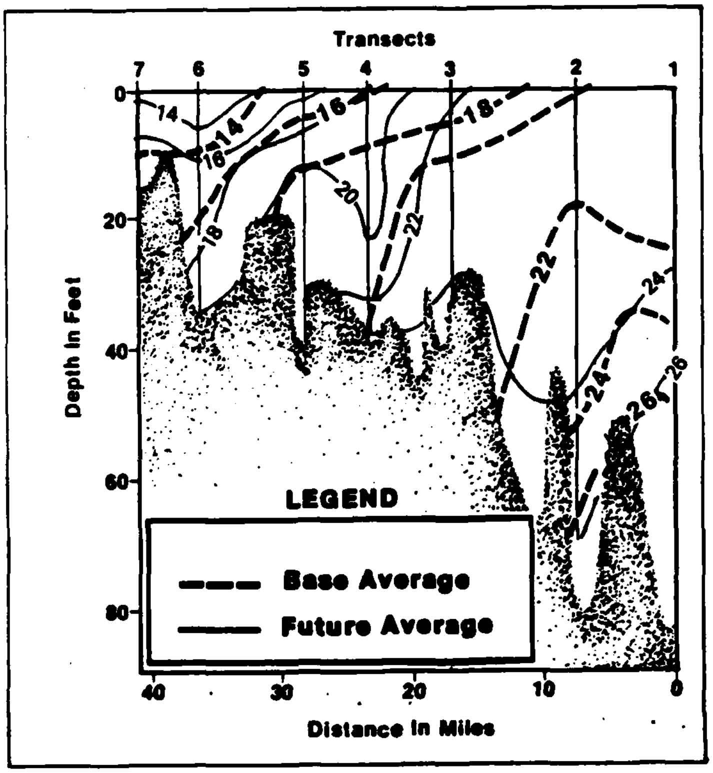


PLATE D-88 LONGITUDINAL SALINITY PROFILES - YORK - SUMMER



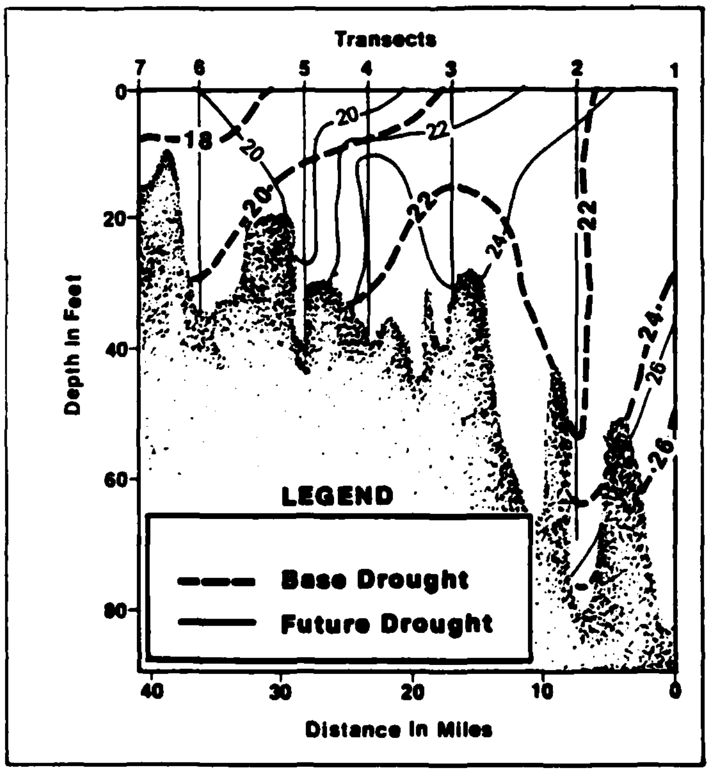
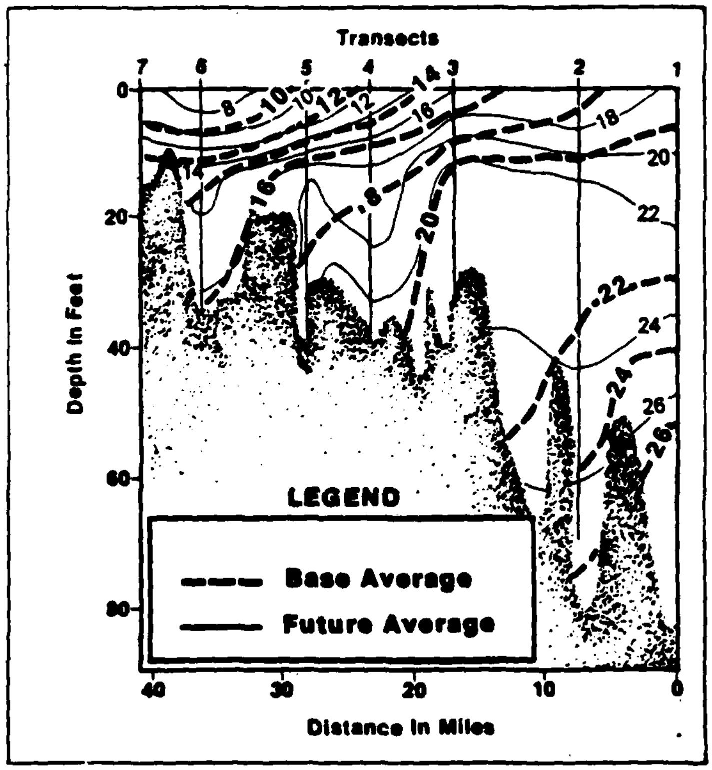


PLATE D-89

LONGITUDUDINAL SALINITY PROFILES - YORK - FALL



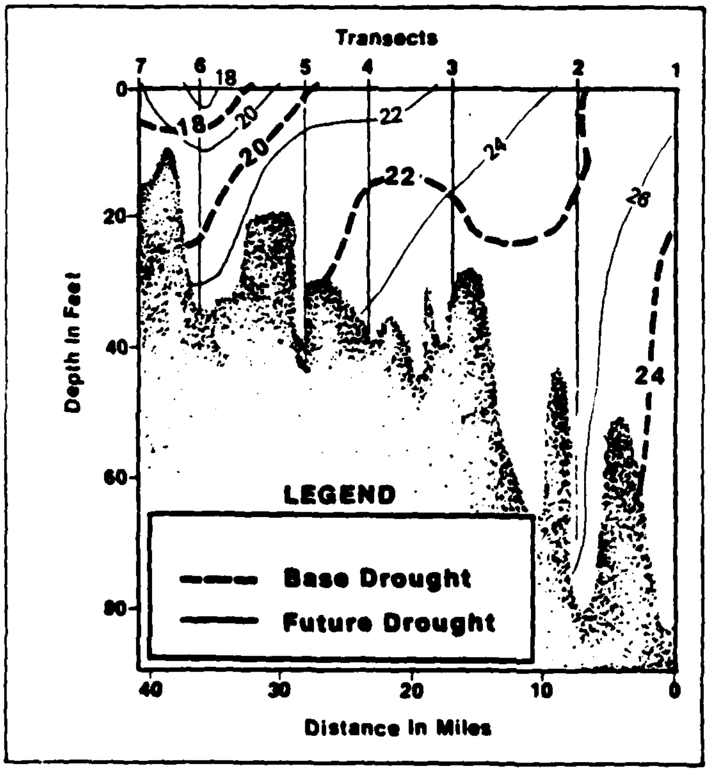
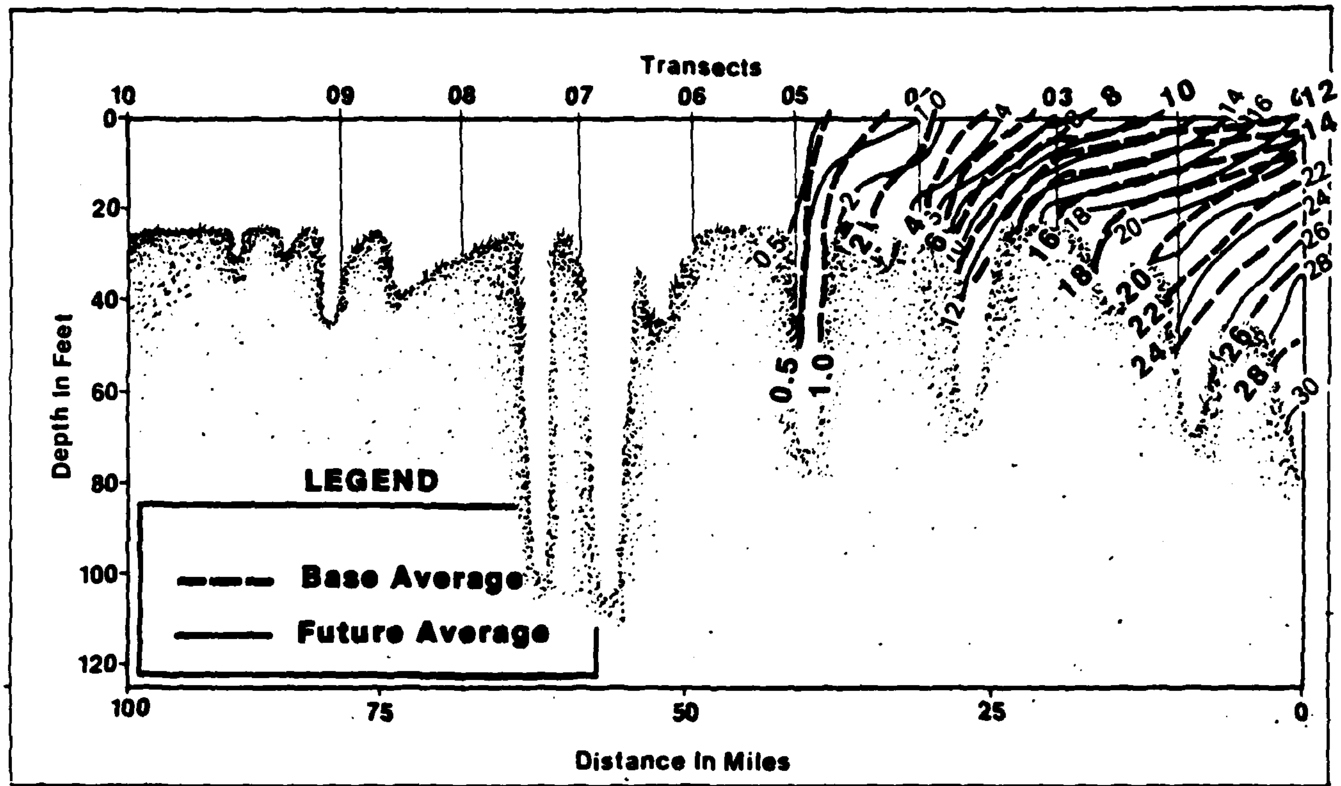


PLATE D-90

LONGITUDINAL SALINITY PROFILES - YORK - WINTER



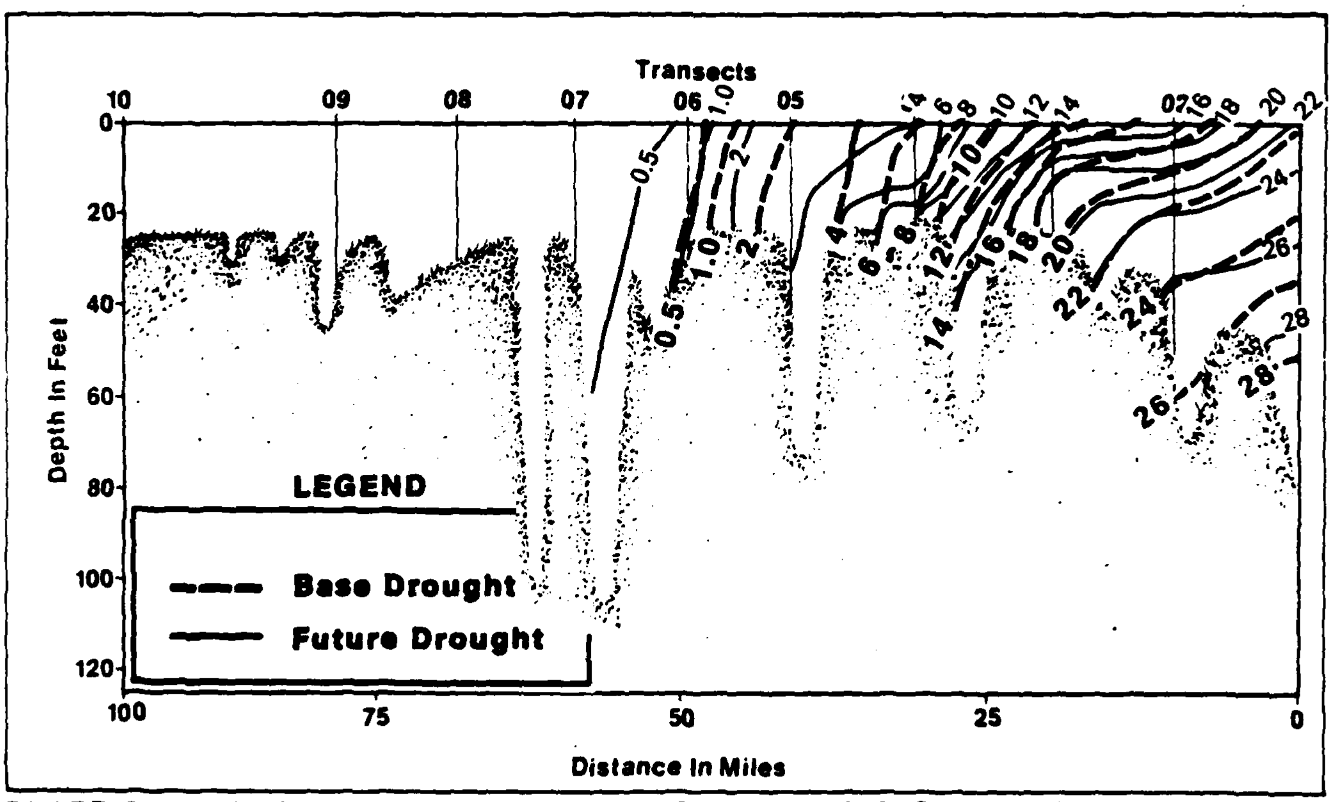
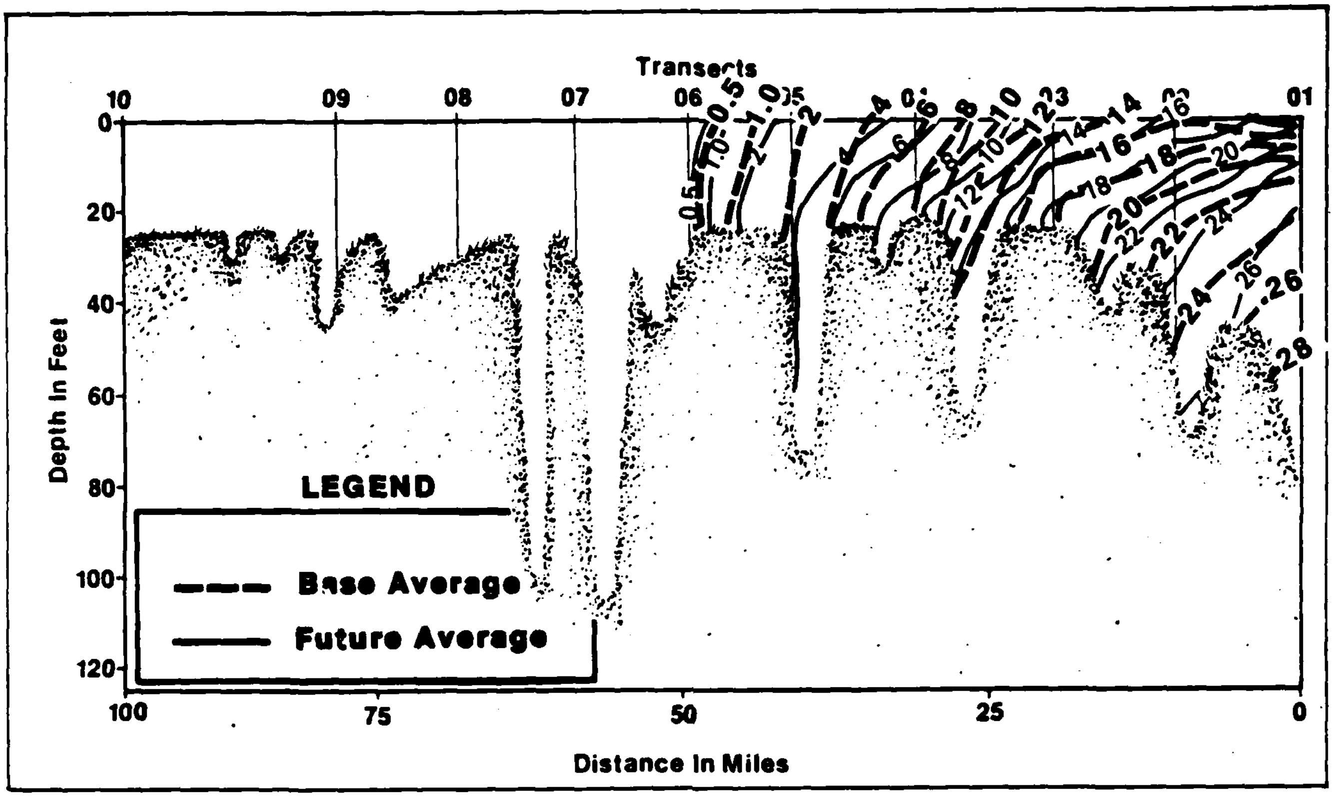


PLATE D-91 LONGITUDINAL SALINITY PROFILES - JAMES - SPRING



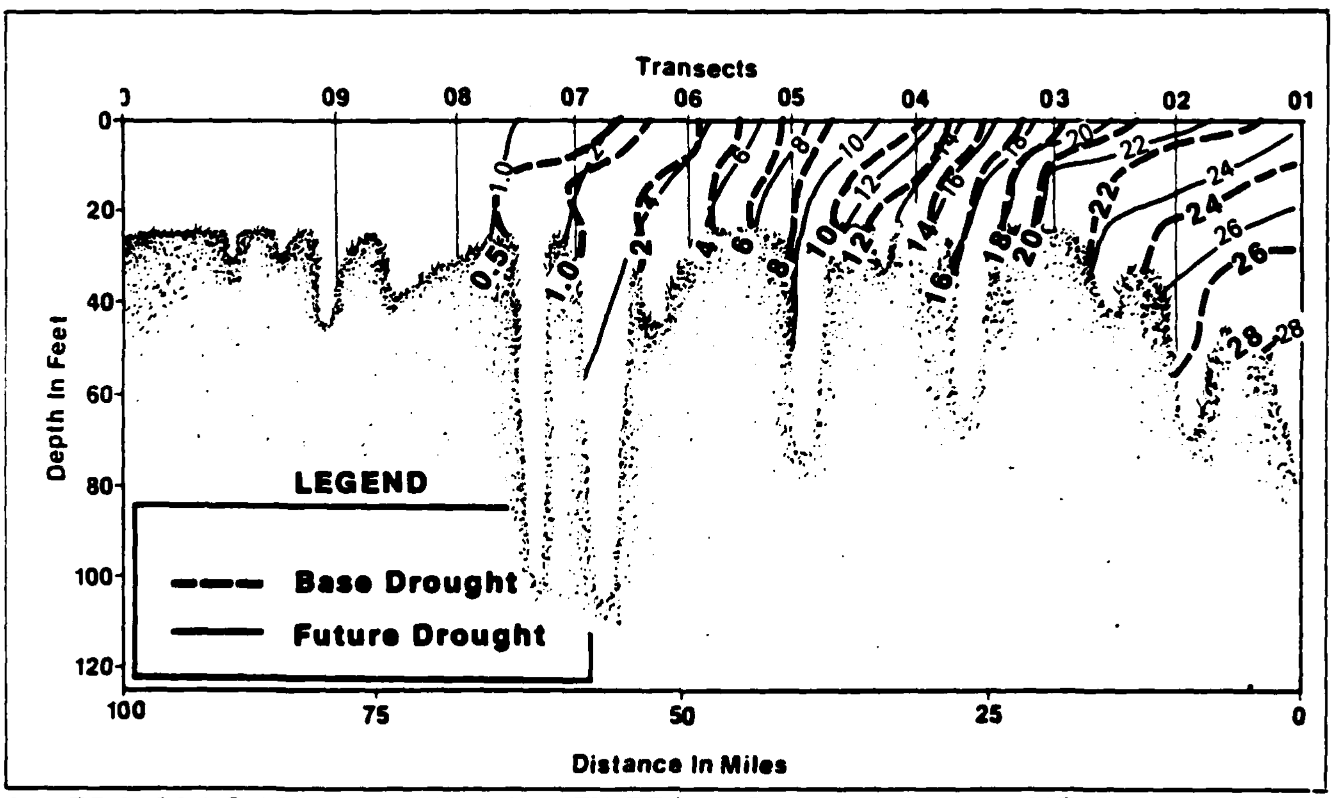
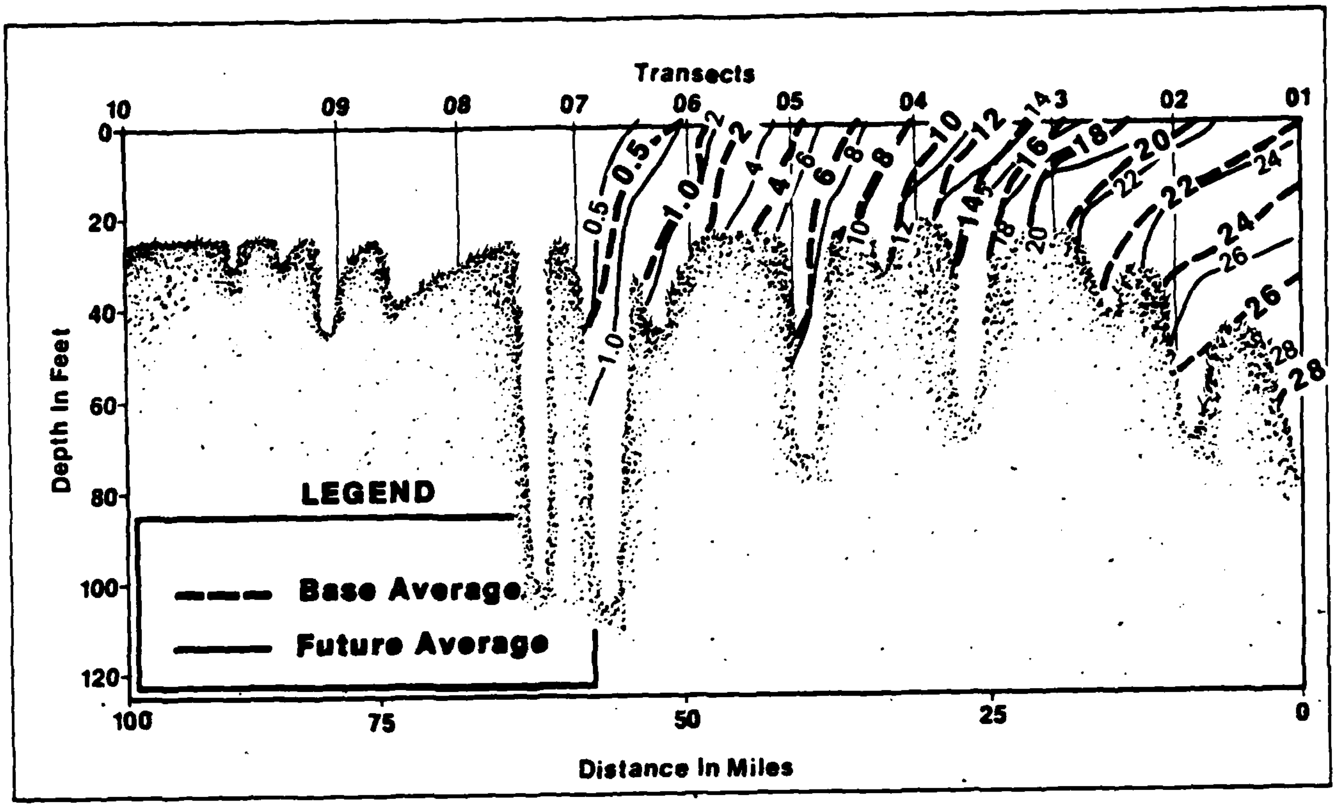


PLATE D-92 LONGITUDINAL SALINITY PROFILES - JAMES - SUMMER



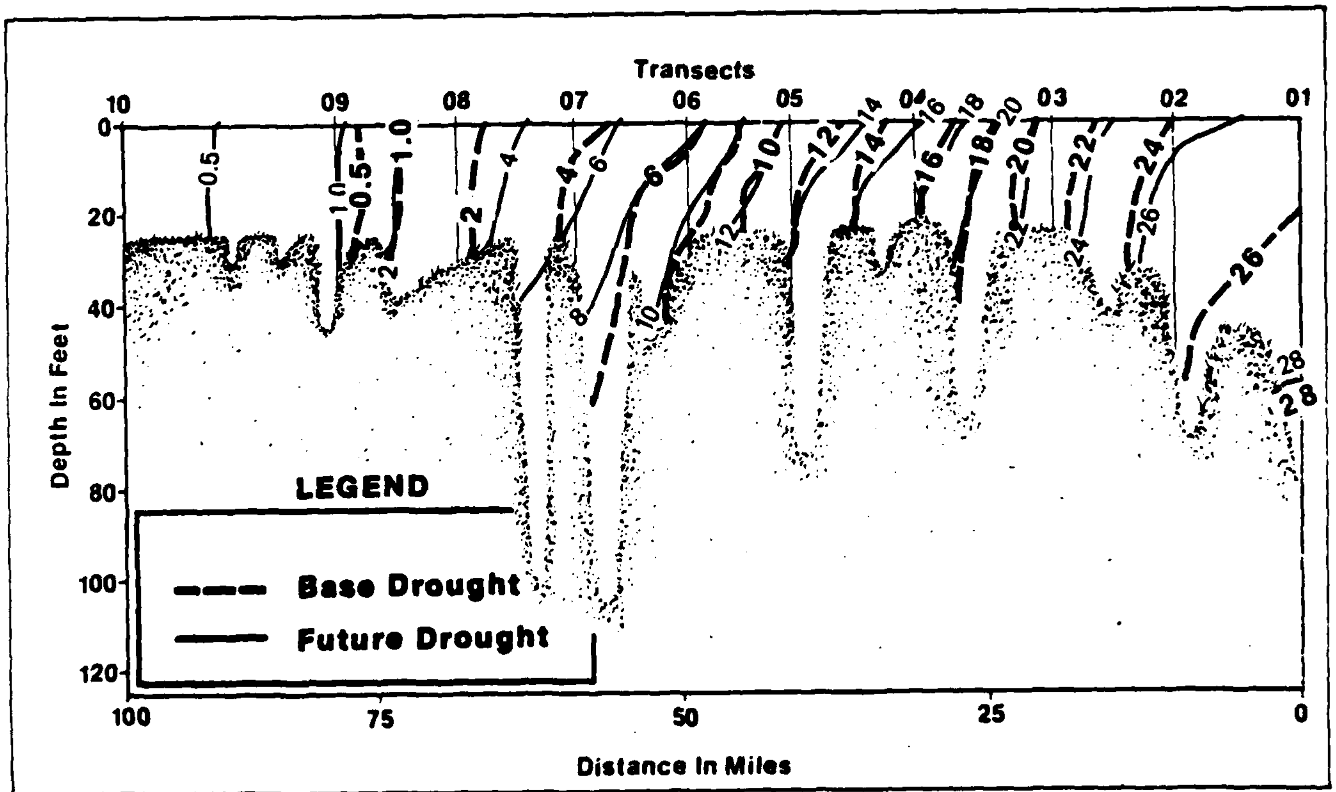
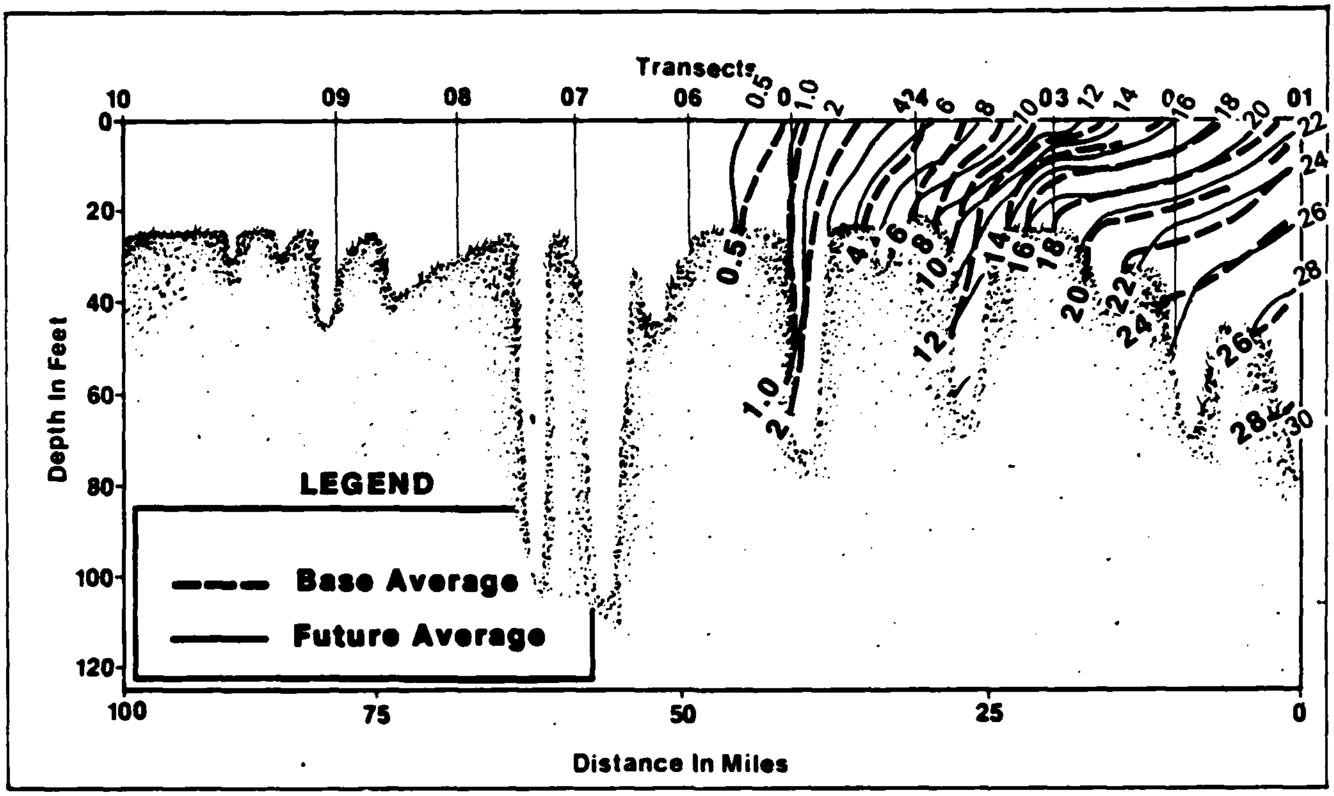


PLATE D-93 LONGITUDINAL SALINITY PROFILES - JAMES - FALL



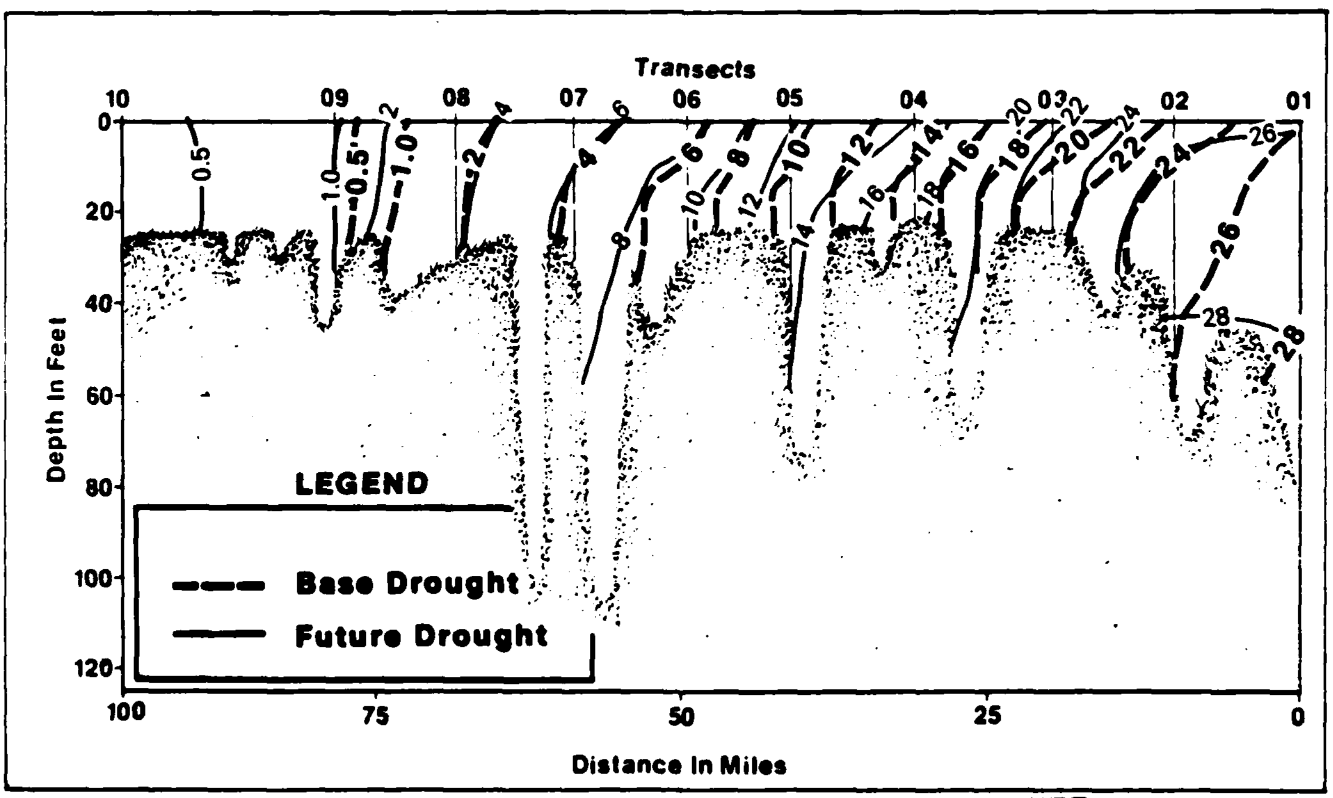


PLATE D-94 LONGITUDINAL SALINITY PROFILES - JAMES - WINTER

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